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HELMET MOUNTED DISPLAYS: AN EXPERIMENTAL INVESTIGATION OF DISPLAY LUMINANCE AND CONTRAST

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FOR THE COMMANDER

Charles Bates

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This study was carried out in order to validate experimentally the predictions of previous analytic work (Cohen, 1973). The objective was to determine the best combination of filter coatings and display luminances required for viewing the Helmet Mounted Display (HMD) against a wide, but operationally realistic variety of background luminances. The predictions relating beamsplitter transmittance, visor transmittance and display luminance to performance were largely supported by the data.

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SECTION I

INTRODUCTION

OBJECTIVE

The objective of this study was to determine under controlled laboratory conditions the best combination of filter coatings and display luminances required for employing the Helmet-Mounted Display against a wide but operationally realistic variety of background luminances.

BACKGROUND

The Helmet Mounted Display (HMD) is a unique display system. It projects a collimated cathode ray tube (CRT) image onto a partially reflective beam-splitter located in front of one of the observer's eyes -- usually the right. The beamsplitter reflects approximately 90 percent of the display luminance projected onto it. Also, it transmits approximately seven percent of the light from the outside world, so that the observer is able to see through the display with his "display eye". The helmet visor, on which the display is presented, transmits approximately 14 percent of the external light. The two eyes are, therefore, exposed to both different amounts of light and different visual images.

The interocular difference in luminance varies as a function of the following four variables: ambient light, display luminance, visor transmittance, and beamsplitter reflectance/transmittance. By optimizing the values of these variables, the display will be visible against background conditions ranging from 10,000 ft-Lamberts in bright sunlight at high altitudes, to 10 ft-Lamberts during night time operations.

STATEMENT OF THE PROBLEM

The wide ranges of background luminance to which operators are exposed produce a variety of problems unique to see-through displays. High levels of ambient light will wash out the displayed imagery. The contrast between this imagery and the background can be increased in two ways:

(a) Background luminance can be attenuated by increasing the density of the visor. However, when the ambient light level is low, it will be correspondingly difficult to see through the visor at all.

(b) In order to allow the visor to be used under low ambient lighting conditions, the transmittance of the beamsplitter rather than of the visor should be reduced. Then the two eyes would receive very different imagery. If the luminances of the two images are similar, the observer can readily attend to either image by alternating his attention. However, when the light levels of the two images become very different, the brighter image may actually suppress the other image, effectively blinding the observer in one eye. For example, if the display luminance was significantly greater than the light transmitted to the non-display eye, the observer might not be able to read his cockpit instruments.

Cohen (1973) evaluated the effects of 480 possible combinations of display luminance, background luminance, and light attenuation on anticipated visual performance. These predictions in conjunction with the empirical data obtained in this study represent a significant contribution to the determination of human visual requirements for designers of visually coupled systems.

SECTION II

VARIABLES AFFECTING VISUAL PERFORMANCE

INDEPENDENT VARIABLES

Under ideal conditions, we would like to maximize the contrast of the HMD imagery, while at the same time delivering equal amounts of light energy to the two eyes. The visor-transmitted light going to both eyes, and the CRT imagery going to the display eye, must be modulated in some way so that acceptable visual performance is obtained under a wide variety of background luminance conditions. Figure 1 shows how this modulation occurs.

Ambient light, expressed in terms of L_B, the background luminance, reaches the observer's eyes via the helmet visor. The visor reduces the level of the incoming light, only transmitting a portion of it. The attenuation is expressed in terms of visor transmittance, V_X. The resultant visor-transmitted light, B_V is given by

$$B_V = L_B \cdot V_X \tag{1}$$

This light goes to the non-display eye without further attenuation.

The visor has a partially reflective, partially transmissive area on which the CRT picture can be delivered. This surface further reduces the incoming light. And this reduction is expressed in terms of beamsplitter transmittance, B_X. The net background luminance on the beamsplitter, B_B is given by

$$B_B = B_V \cdot B_X \tag{2}$$

The beamsplitter, in addition to reducing visor-transmitted light, also reflects the light projected to it from the face of the CRT display to the observer's display eye. The amount of display luminance, L_D, transmitted to the observer is a function of how much of the display energy is reflected from the posterior surface of the beamsplitter, and how much is absorbed by the beamsplitter. Absorption typically amounts to 1 to 2 percent and it was assumed that it could be ignored, thus simplifying the present analysis. Since the sum of beamsplitter transmittance (B_X) and beamsplitter reflectance.

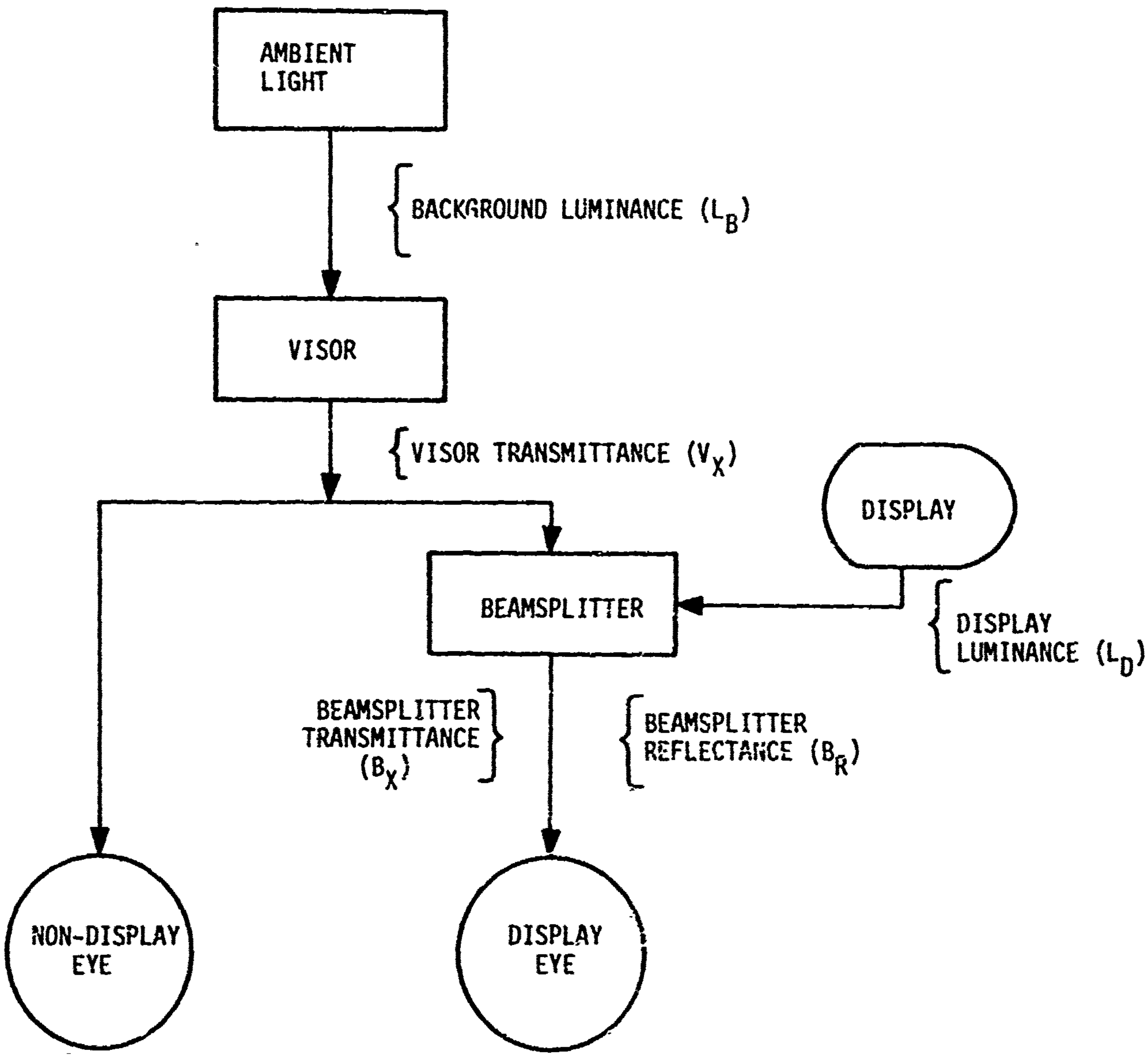

Figure 1. Block Diagram of Independent Variables which Influence HMD Luminance and Contrast

(B_R) was assumed to equal unity, then it follows that

$$B_R = 1 - B_X \tag{3}$$

The net display luminance on the beamsplitter, B_D, is given by

$$B_D = L_D \cdot B_R + B_B \tag{4}$$

Using the above formulations the following four independent variables were systematically varied in the present study:

(1) background luminance, L_B;
(2) visor transmittance, V_X;
(3) beamsplitter transmittance, B_X;
(4) display luminance, L_D.

DEPENDENT VARIABLES

Selected values of L_D, B_X, V_X and L_B were used to predict visual performance in terms of display contrast and interocular luminance differences.

Contrast is expressed as a ratio. It indicates the relative luminance of a figure with respect to the luminance of the background. Most commonly it is expressed as the proportional increase in luminance contributed by the figure, thus:

$$\text{Contrast} = \frac{L_{Figure} - L_{Background}}{L_{Background}} \tag{5}$$

Classical contrast work, like the Tiffany study (Blackwell, 1946) and more recent work by Carel (1965) use this expression. Van Nes and Bouman (1967) suggest the use of a contrast modulation function:

$$C = \frac{B_{max} - B_{min}}{B_{max} + B_{min}} \tag{6}$$

Where B_{max} and B_{min} are the highest and lowest luminance values of the display, respectively.

With a see-through display, the display luminance will always be greater than the background luminance. Using equation (5), the contrast values in the present study can take any value between zero and infinity.

However, to make the data compatible with the contrast values used in engineering specifications for CRT displays, equation (6) was used in this study.

An equation (5) contrast value, C_D, can be converted to an equation (6) modulation contrast, C_M, as follows:

$$C_D = \frac{2C_M}{1-C_M} \tag{7}$$

To derive contrast for the HMD, it is necessary to know the maximum and minimum luminances of the display that could be obtained given fixed values of L_B, V_X, and L_D. Maximum luminance would be achieved when maximum net background luminance is combined with maximum display luminance on the inner (posterior) surface of the beamsplitter. Thus, maximum luminance would be equal to B_D. Minimum luminance would involve the net background luminance alone, B_B. Given these maximum and minimum luminances, the resulting contrast is the maximum possible contrast, C_{max}. This is given by

$$C_{max} = \frac{B_D - B_B}{B_D + B_B} \cdot (100) \tag{8}$$

C_{max} is expressed as a percentage by equation (8).

Interocular luminance differences are a function of the difference between the light transmitted to the display eye, B_D, and to the non-display eye, B_V. There are several combinations of values of L_D, B_X, V_X, and L_B that produce situations where B_D and B_V are close enough in luminance for the observer to feel no effect. Then, if the C_{max} is high enough for the observer to see the display comfortably, we would have a good visual environment with optimal performance likely. On the other hand, if B_D and B_V differ greatly, even an ideal C_{max} value could not guarantee optimal performance.

Differences in luminance may result in phenomena such as "binocular rivalry" (Cohen and Markoff, 1972), where the observer's attention would alternate from one eye to the other. If the interocular luminance difference was great enough, alternation would give way to suppression with the dimmer field of view not being seen at all. Such a situation could be particularly bad in the air-to-air combat situation, where a very bright display not only would occlude the display eye, but also might suppress the field of view of the non-display eye. onvenient expression for the difference in luminance to the two eyes is interocular luminance difference ratio, B_Δ, which is given by

$$B_\Delta = \frac{B_D}{B_V} \tag{9}$$

When $B_\Delta = 1$, the two eyes would receive equal light energy. When $B_\Delta > 1$ more luminance would be transmitted to the display eye, with the reverse occurring when $B_\Delta < 1$.

VISUAL PERFORMANCE CRITERIA

There is a minimum value of C_{max} below which the display would be so degraded that effective visual performance could not be obtained. There are values of B_Δ that would also produce unacceptable performance.

Cohen (1973) determined acceptable levels of C_{max} and B_Δ. He concluded that any combination of L_D, B_X, V_X, and L_B that resulted in $C_{max} < 23\%$ or $0.25 > B_\Delta > 4.00$ would not be acceptable because of its likely effect on visual performance. The present study is an experimental validation of these performance criteria. If the analytical criteria correspond to actual human visual performance criteria, then the performance predictions of the previous study will have a general applicability to the design and development of future visually coupled systems.

SECTION III

METHOD

The experiment was designed to investigate the effects of various combinations of display luminance, background luminance, and light attenuation on visual performance.

SUBJECTS

Four male undergraduate students from colleges in the Twin Cities participated in the study. All were paid for their participation, and all had normal vision with no specific ocular pathology.

APPARATUS

Figure 2 shows the experimental set-up. Briefly, the system contained the following equipment:

- Two 12-inch by 12-inch rear-projection screens, on which a resolution chart or background pattern was projected by a pair of 1600-watt Xenon-arc sources.

- A Rollei slide projector for projecting an image on one screen. Slide mounted filters provided precise control of the display luminance. In addition, light from this source was filtered to approximate the color of a P-1 phosphor.

- Intertrial adaptation lights. The output of these lights was continuously variable over a wide luminance range.

- A filter system for precise control of background luminance. A filter wheel, simulating the helmet beamsplitter, further attenuated the amount of light available to the display eye.

- An optical assembly which enabled stimuli to be presented independently to either of the subject's eyes.

Stimulus materials consisted of 2-inch by 2-inch slides of a standard Air Force tri-bar chart and a randomly generated reticulated pattern. Figure 3 illustrates both kinds of stimuli. The system was calibrated both in terms

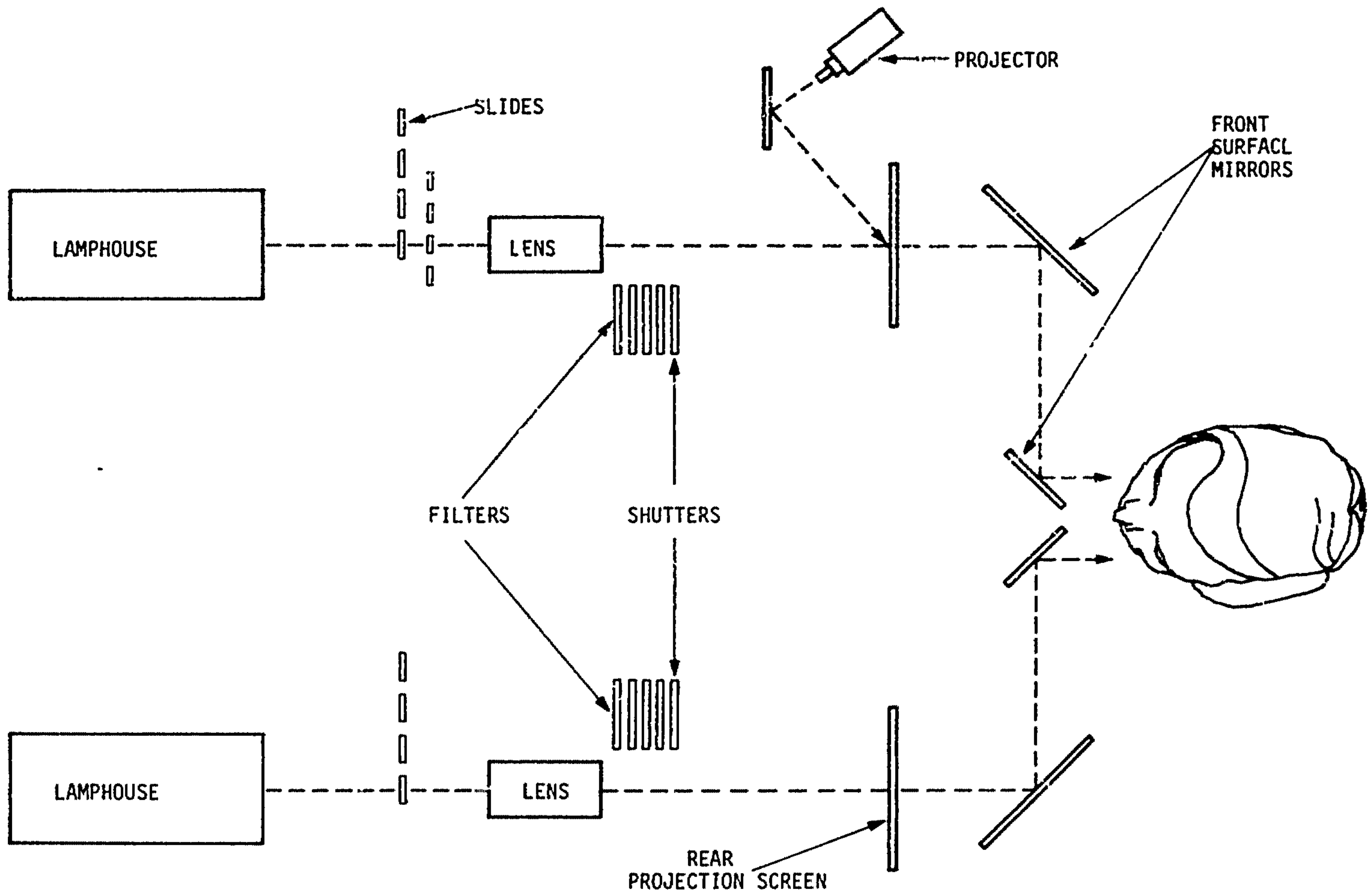

Figure 2. Experimental Set-up

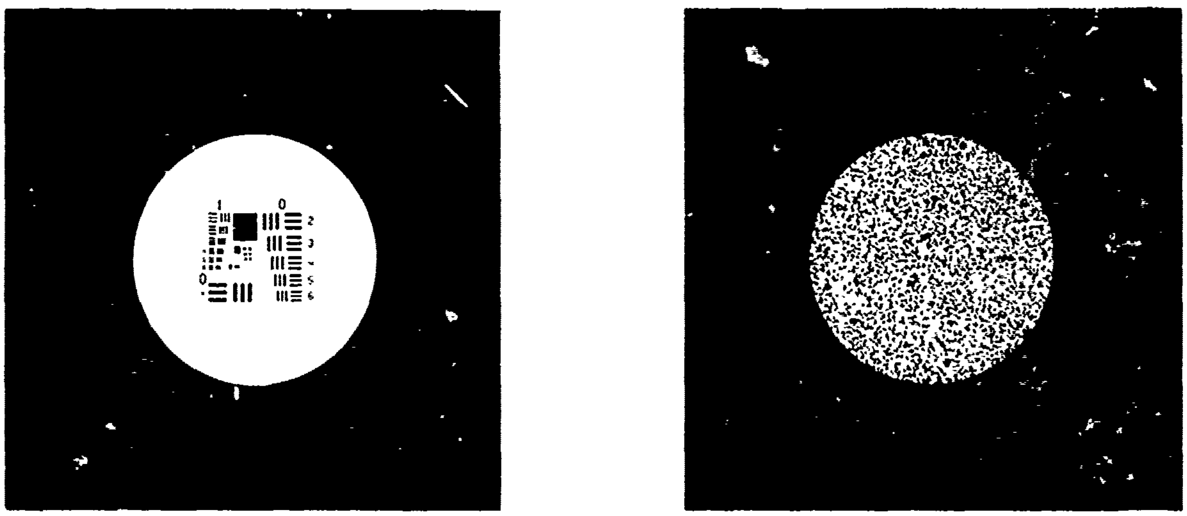

Figure 3. Stimulus Slides

of resolution and luminance. The results of the calibration procedure are given in Appendix B.

PROCEDURE

The subject was initially trained to recognize and identify tri-bar positions on an enlarged resolution chart. Once familiar with this procedure, the subject sat in a dental chair before the apparatus and placed his head on a padded rest on the optical stand. In this position, distinct, non-overlapping fields of view were presented to each eye.

Next, the experimenter read the instructions aloud (the instructions are given in Appendix A). Subjects were told to maintain proper head position and to use both eyes at all times. The subject's task was to report the positions of the smallest vertical and horizontal bar patterns he could resolve.

The study consisted of five blocks of 35 conditions. Each block represented one value of combiner transmittance (B_X) with transmissivity increasing across blocks. Within these blocks, five levels of display luminance, L_D, were presented in order of increasing luminance. For each L_D value seven levels of background luminance were presented, always increasing in luminance.

Subjects received all test conditions. There were ten trials per condition. On five consecutive trials the chart was presented to the display eye only, by means of the slide projector, against a reticulated pattern from the lamphouse presented to both eyes. This situation presumably evaluated the subject's ability to utilize the displayed imagery against a wide variety of luminance conditions. In the remaining five trials, it was presented to both eyes via the lamphouses, while the right eye received an additional background pattern from the slide projector. Here, the "see-through" case was being evaluated, i.e., the subject's ability to resolve visual stimuli of varying intensity outside the visor was being tested as a function of net display luminance. The order of chart position was counterbalanced across conditions.

Between trials, the subject's eyes were light adapted to a field matching the background luminance level of the next trial, which was, as previously mentioned, always more intense. This procedure was adopted to minimize any adaptation level phenomena that might have interferred with the subject's performance.

Each subject received ten practice trials. Response time and bar positions were recorded. These values provided base levels during later analysis. Upon completion of the practice trials, formal data collection began. Response time and bar positions were recorded for each trial. The experimental sessions lasted one hour. Subjects could rest whenever they felt fatigued. There were approximately 16 sessions per subject.

TEST CONDITIONS

Section II of this report identified the following independent variables as crucial to visual performance with a see-through, monocular HMD:

1. L_B, background luminance

2. L_D, display luminance

3. V_X, visor transmittance

4. B_X, beamsplitter transmittance

Representative levels of these variables are given in Table 1. Note that values of background luminance, L_B, and visor transmittance, V_X, have been combined as the visor transmitted light, B_V, using equation (1), viz:

$$B_V = L_B \cdot V_X$$

Values in Table 1 are given for both chart location conditions.

Table 1.

Values of L_D, B_V, and B_X

1. Display Luminance (L_D) (ft-Lamberts)		
	A	12.3
	B	23.7
	C	50.5
	D	150.0
	E	231.0
2. Visor Transmitted Light (B_V)		
	A	0.7
	B	2.4
	C	6.4
	D	27.5
	E	88.0
	F	310.0
	G	975.0
3. Combiner Transmittance (B_X)		
	A	0%
	B	4%
	C	10%
	D	25%
	E	Trichroic

SECTION IV

RESULTS

The display luminance and contrast experiment provides a test of the analytic work completed earlier in the contract and previously submitted to AMRL (Cohen, 1973).

The average resolution and average response time of the four observers is shown in Table C-1 of Appendix C for all 175 conditions. These data provide the basis for Figures 4-10. The predictions made relating beam-splitter transmittance, B_X, visor transmittance, B_V, and display luminance, L_D, to resolution performance were supported by the data. Specific findings were:

1. For imagery displayed on the HMD, contrast or C_{max} becomes critical at 23 percent (as is clear from Figure 4). Below this value visual performance deteriorates markedly. Above 23 percent visual performance remains stable. The value obtained here coincides with that predicted in the analysis.

2. As Figure 5 shows, resolution ability for background imagery is unaffected until C_{max} exceeds 98 percent; i.e. "see-through" ability is unchanged as C_{max} ranges from 0-98 percent.

3. Figure 6 shows that, when the interocular luminance ratio, B , (luminance in display eye divided by luminance in other eye) falls below 0.3, visual performance deteriorates markedly for imagery displayed on the HMD. A value of 0.25 was expected from the analysis.

4. Interocular luminance ratios above 10.0 significantly interfere with the subject's ability to see through the visor with both eyes open. This is illustrated by Figure 7. Analysis had predicted an upper value of 4.0.

5. Figure 8 shows that, when visor transmitted light (B_V) approaches 1,000 ft-Lamberts (10 percent visor at 10,000 ft-Lambert ambient), display luminances L_D, at the eye of less than 200 ft-Lambert sharply degrade visual performance.

6. The same figure (8) shows that, when visor transmitted light (B_V) is less than five ft-Lamberts, even a 12 ft-Lambert display interferes with outside-the-visor visual performance, and it does so regardless of beamsplitter transmittance (amount of see-through in the display area).

7. Figure 9 shows that the lower the display luminance, (L_D) is, the lower the beamsplitter transmittance (B_X) must be in order to resolve targets presented on the display.

8. However, as display luminance, L_D, increases above 100 ft-Lamberts, beamsplitter transmittance, B_X, becomes less critical as a determiner of visual resolution (Figure 9).

9. Figure 10 shows that, as visor transmitted light, B_V, increases above 100 ft-Lamberts, visual resolution of the display deteriorates as beamsplitter transmittance, B_X, increases.

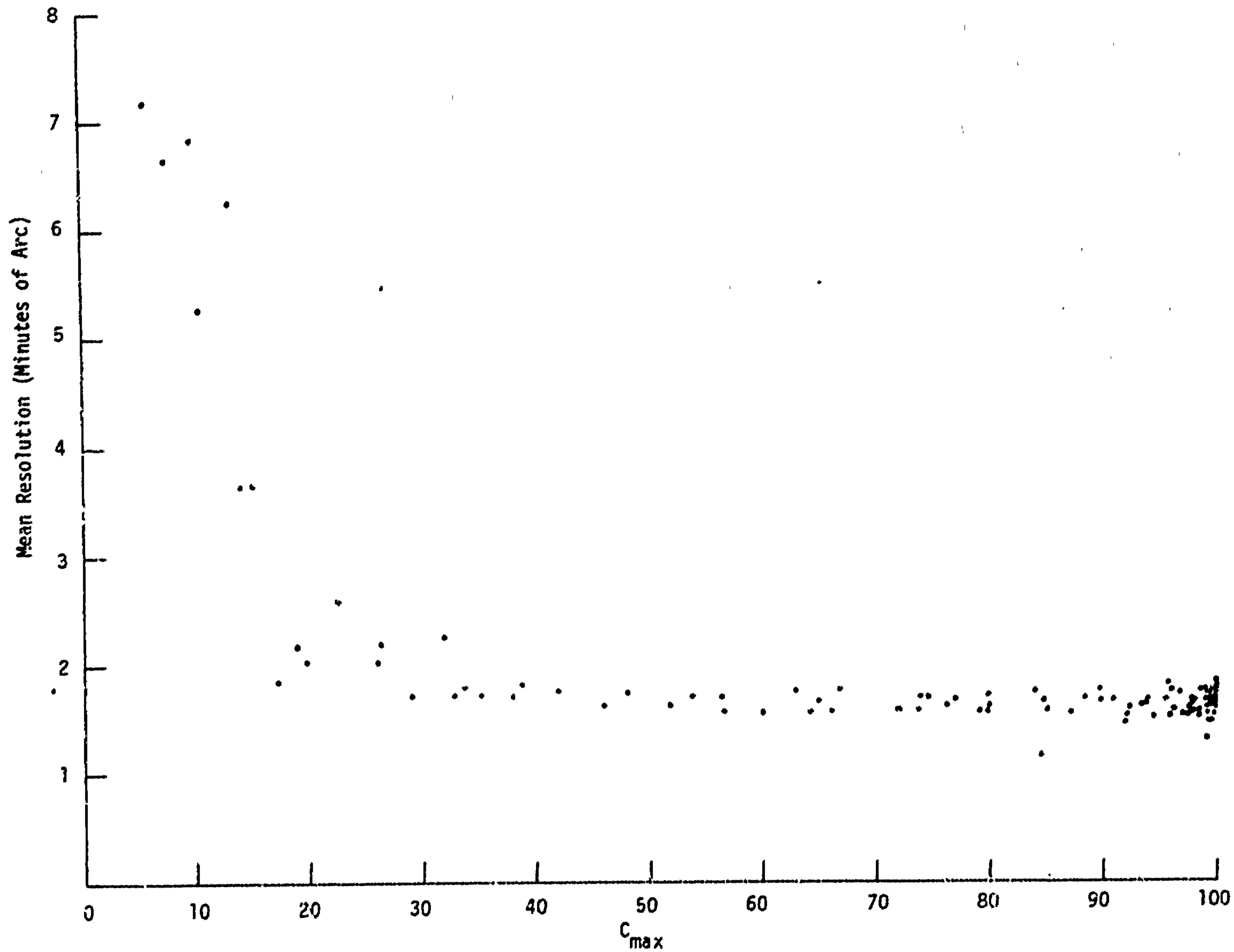

Figure 4. Mean Resolution as a Function of C_{max} for Imagery Displayed on the HMD

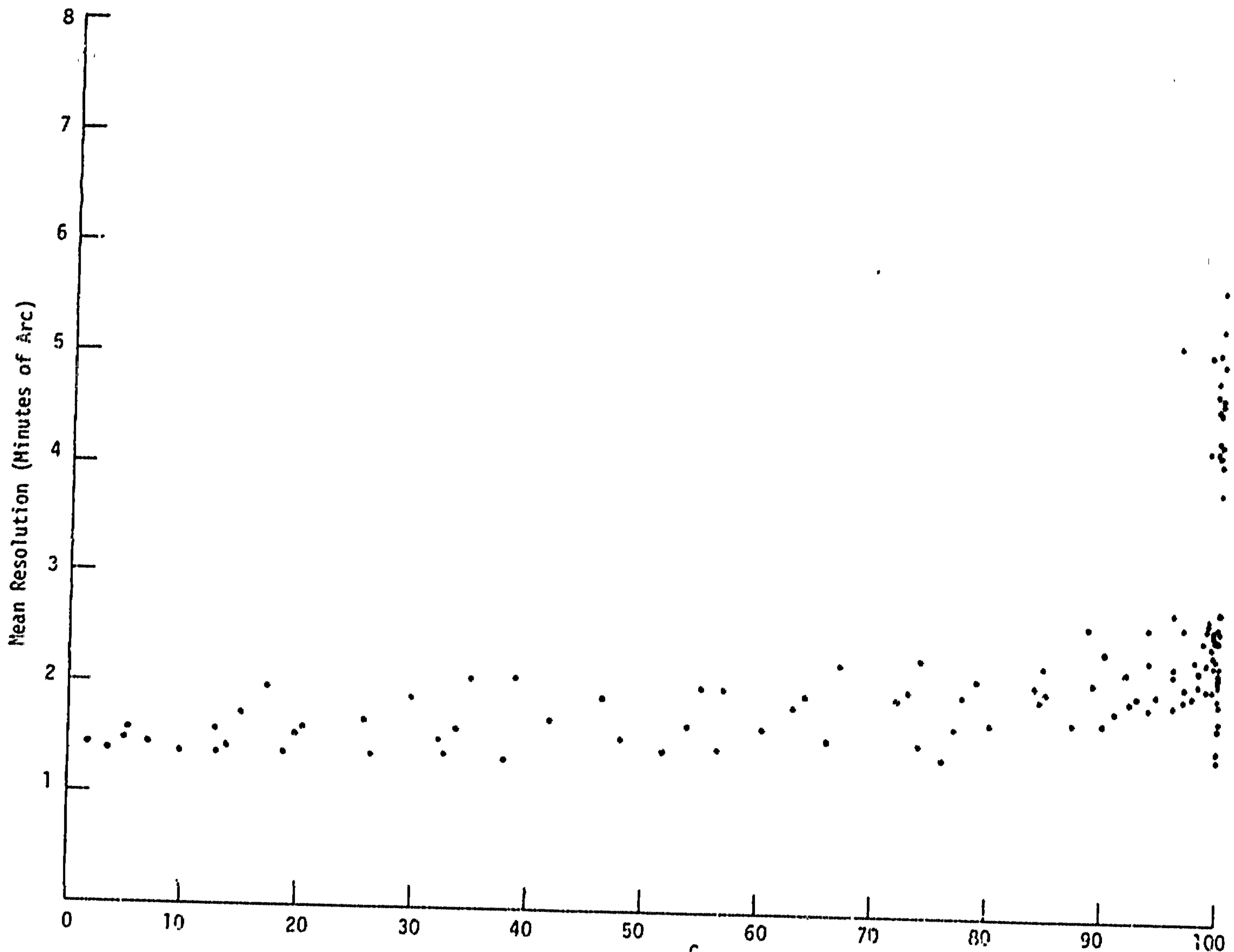

Figure 5. Mean Resolution as a Function of C_{max} for Background Imagery

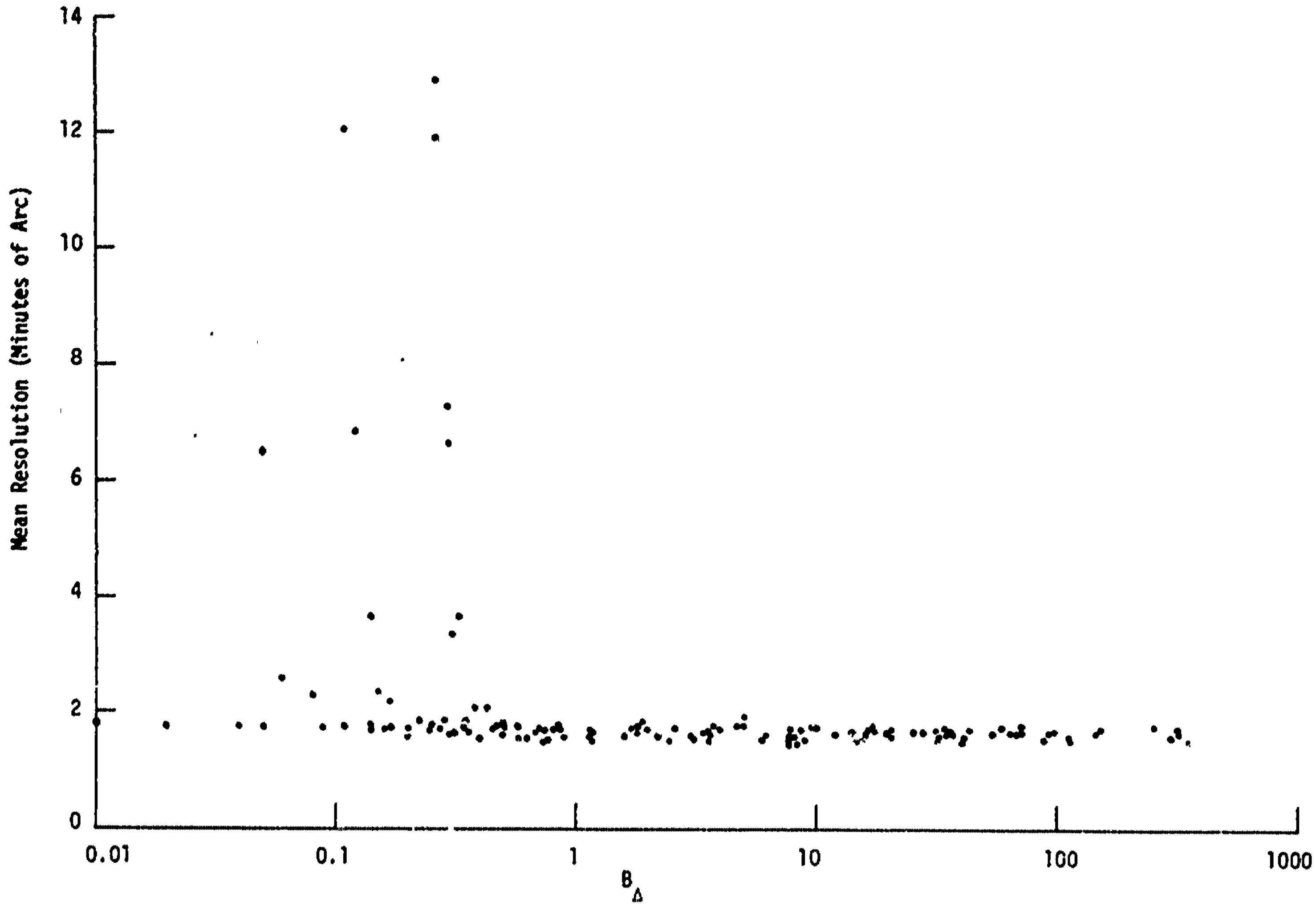

Figure 6. Mean Resolution as a Function of B_Δ for Imagery Displayed on the HMD

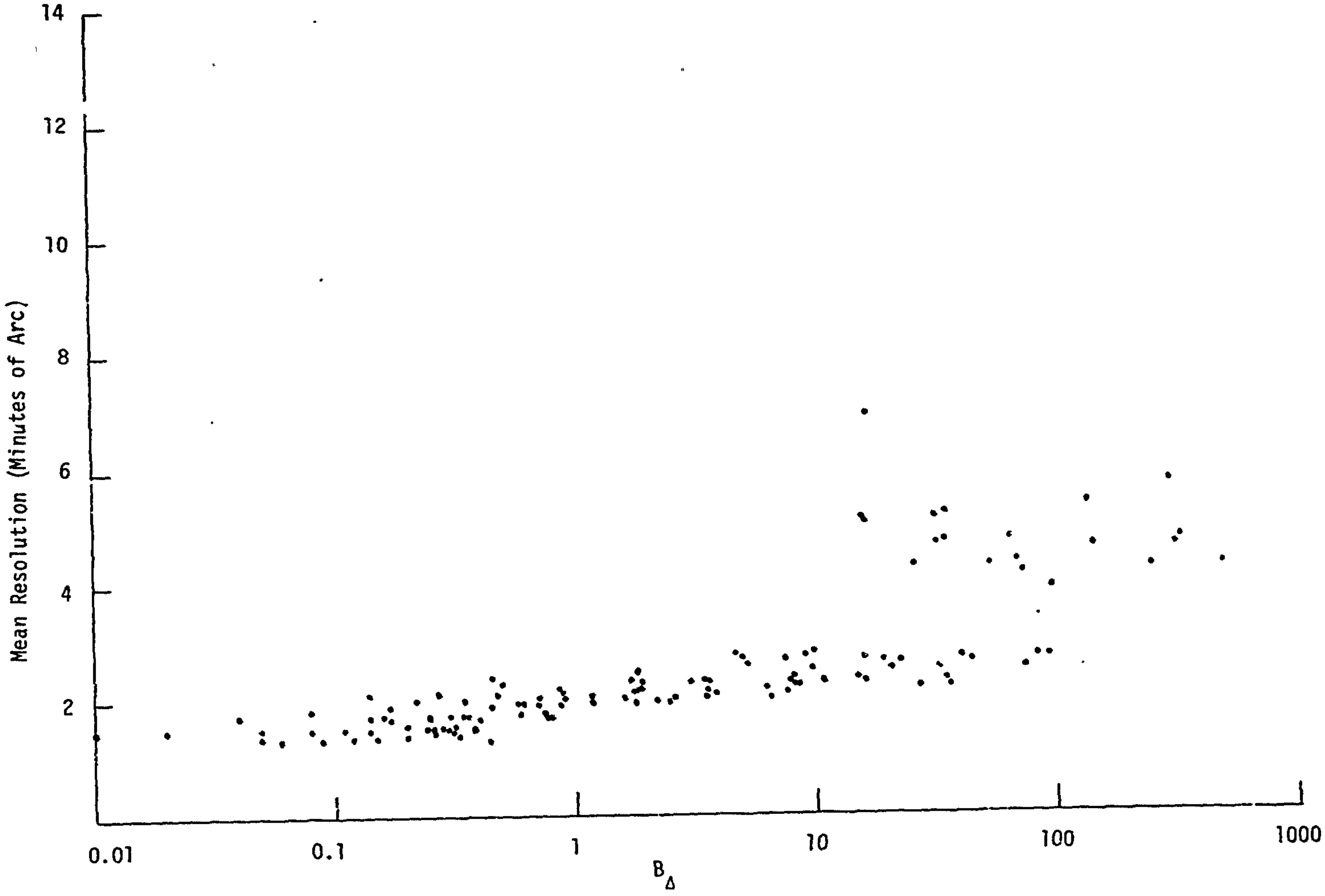

Figure 7. Mean Resolution as a Function of B_Δ for Background Imagery

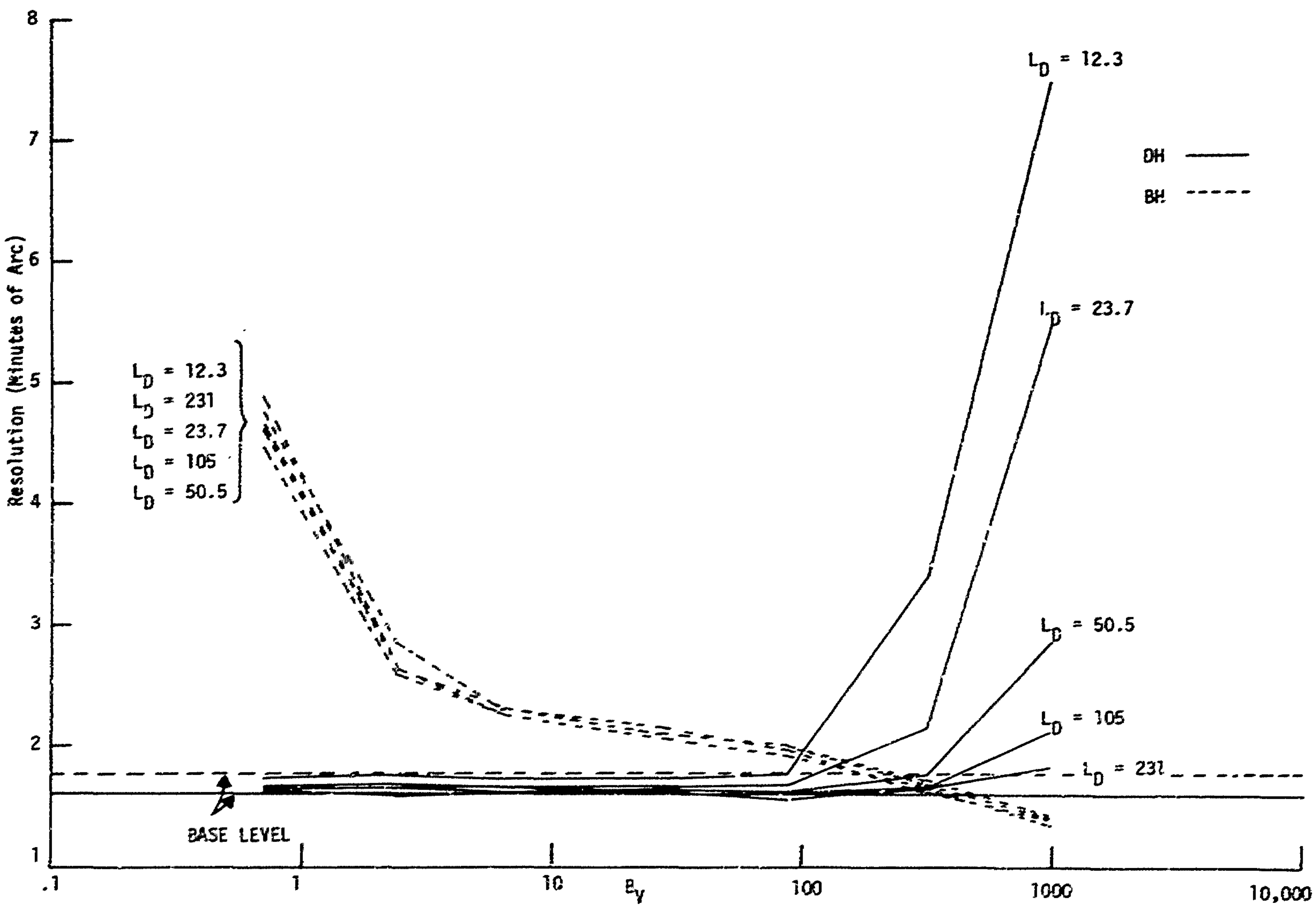

Figure 8. Mean Resolution as a Function of B_V
(DH - imagery displayed on HMD; BH - background imagery)

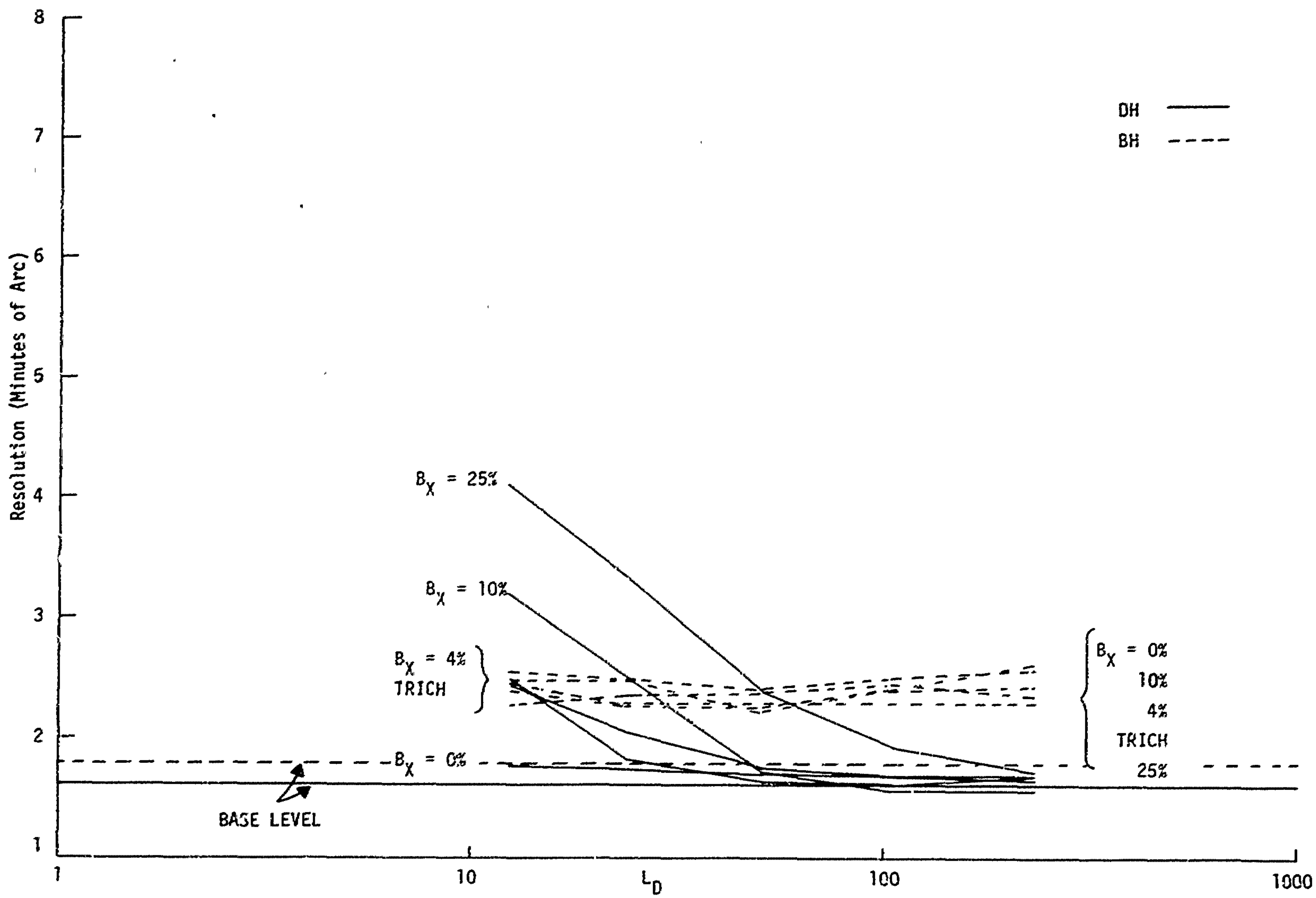

Figure 9. Mean Resolution as a Function of L_D

(DH - imagery displayed on HMD; BH - background imagery)

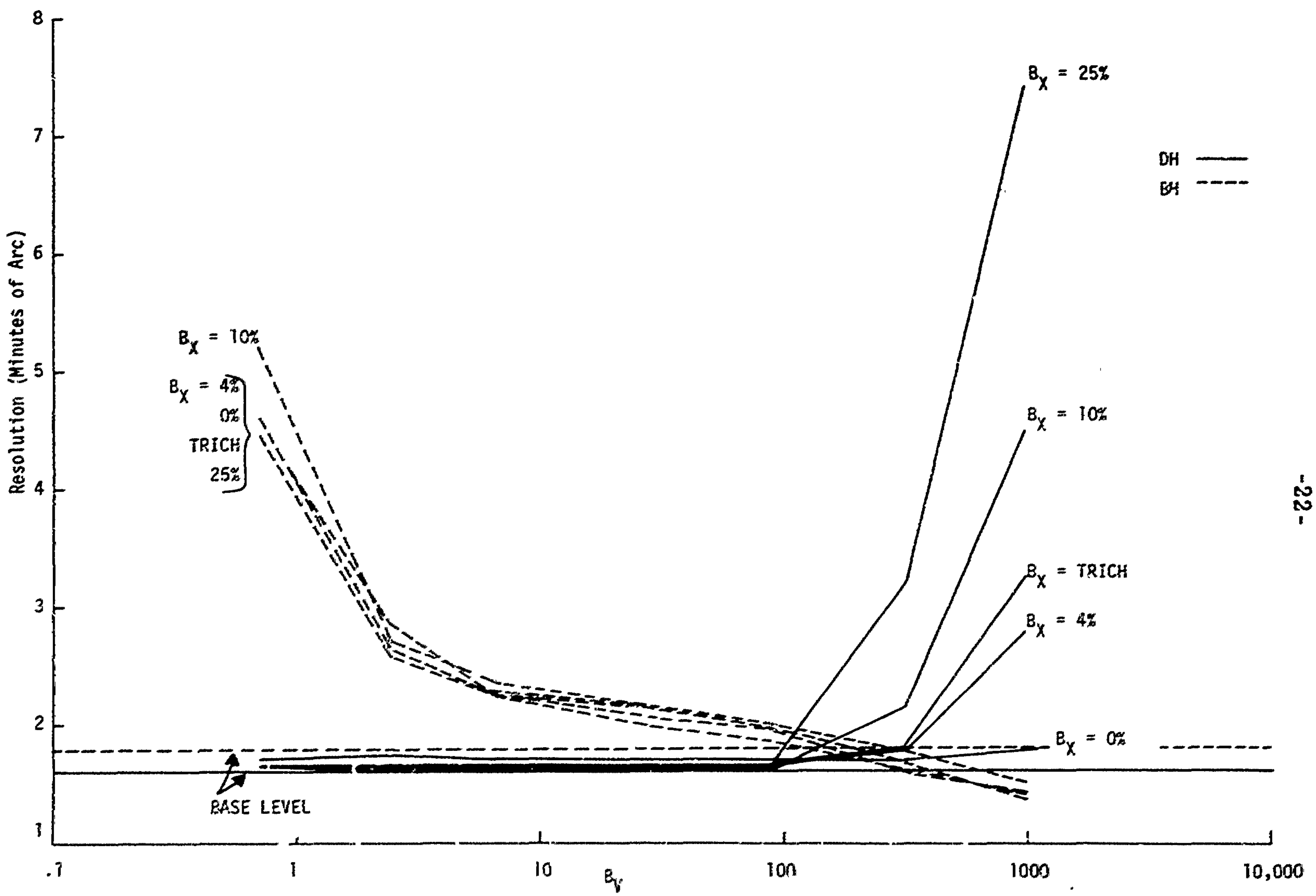

Figure 10. Mean Resolution as a Function of B_X

(DH - imagery displayed on HMD; BH - background imagery)

SECTION V

CONCLUSIONS

This study confirmed the conclusion of our analytic work (Cohen, 1973) that no single combination of visor transmittance (V_X), beamsplitter transmittance (B_X), and display luminance (L_D) will allow acceptable visual performance, from the standpoint of both display contrast (C_{max}) and interocular luminance differences (B_Δ), across the anticipated operational range of background luminance conditions, with L_B ranging from 10 to 10,000 ft-Lamberts.

In summary, the study demonstrates the need for:

(a) A variable transmission visor with a range from close to 100% down to less than 1%.

(b) A variable transmission beamsplitter with an approximate range of 25% down to 0%.

(c) A maximum display luminance, at the eye, of approximately 200 foot-Lamberts.

SECTION VI

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APPENDIX A

INSTRUCTIONS TO SUBJECTS

1. "In this study, we want to evaluate a series of lighting conditions that may affect human vision".

2. "Your job will be to identify and report the smallest group of three bars you can resolve -- that is, distinguish between the black bars and white spaces between bars".

3. Experimenter shows subject an $8\frac{1}{2}$ x 11 resolution chart and demonstrates how to read it. Then E points rapidly to different bar groupings and has S verbally identify the groups until he can correctly report ten without error.

4. "This resolution chart will be shown on the screen in front of you. Please look only at the screen. During its presentation, I want you to do two things:

   a) Report the smallest group of vertical bars that you can resolve without squinting.

   b) Now do the same for the horizontal bars".

5. "We will be measuring the time it takes you to respond, but we are more interested in the accuracy of your response. Remember, accuracy is more important than speed. If you are not sure of your response, tell us. Please report only the group of lines that you can see clearly".

6. "It is very important that you report only what you can see. If you are not sure, don't report it. Please do not guess".

7. "Please keep both eyes open at all times". (Repeat)

8. "You will be participating in this study for a number of days. The task is tiring and will require frequent rests. If you feel any fatigue or eye strain, please tell me immediately and we will take a break".

9. Seat S and adjust chair until comfortable. Then go through condition 19 until S is able to perform both tasks easily for ten consecutive trials.

10. "All right -- it looks as if you are ready to begin. Any questions? If not, let's begin".

APPENDIX B

CALIBRATION DATA

Tables B-1 through B-4 show the results of resolution calibrations made for the night field alone, the displayed image alone, the left field alone for the night field under all 175 experimental conditions.

Tables B-5 through B-8 show similarly the results of luminance calibrations.

Table B-1.

Calibration of Resolution for the Right Field with the Background Projector Only

B_X	B_V (ft-Lamberts)	Vertical Bars	Horizontal Bars	Average Resolution (Minutes of Arc)
4%	0.7	0-1	0-1	17.65
	2.4	1-1	1-1	8.83
	6.4	1-4	1-4	6.20
	27.5	2-4	2-4	3.10
	88.0	2-6	2-6	2.48
	310.0	4-1	4-1	1.10
	975.0	5-1	5-1	0.55
10%	0.7	0-5	0-5	11.05
	2.4	1-4	1-4	6.20
	6.4	2-2	2-2	3.93
	27.5	2-6	2-6	2.48
	88.0	3-1	3-1	2.21
	310.0	4-2	4-2	0.98
	975.0	5-2	5-2	0.49
25%	0.7	1-1	1-1	8.83
	2.4	1-6	1-6	4.94
	6.4	2-3	2-3	3.48
	27.5	2-5	2-5	2.76
	88.0	2-6	2-6	2.48
	310.0	4-2	4-2	0.98
	975.0	5-1	5-1	0.55
Trichroic	0.7	0-1	0-1	17.65
	2.4	1-6	1-5	5.53
	6.4	2-2	2-2	3.93
	27.5	3-1	3-1	2.21
	88.0	3-2	3-2	1.97
	310.0	4-4	4-4	0.77
	975.0	5-2	5-2	0.49

Table B-2.

Calibration of Resolution for the Displayed Image with Image Projector Only

L_D (ft-Lamberts)	Vertical Bars	Horizontal Bars	Average Resolution (Minutes of Arc)
12.3	4-1	4-1	1.10
23.7	4-1	4-1	1.10
50.5	4-1	4-1	1.10
105.0	4-1	4-1	1.10
231.0	4-1	4-1	1.10

Table B-3.

Calibration of Resolution for the Left Field with Background Projector Only

B_V (ft-Lamberts)	Vertical Bars	Horizontal Bars	Average Resolution (Minutes of Arc)
0.7	2-6	2-6	2.48
2.4	3-1	3-1	2.21
6.4	3-3	3-3	1.74
27.5	3-4	3-4	1.55
88.0	3-5	3-5	1.38
310.0	4-2	4-2	0.98
975.0	4-4	4-4	0.77

Table B-4.

Calibration of Resolution for the Right Field
Under All 175 Experimental Conditions

Smallest Resolvable Bars for All Conditions

Condition	B_X	L_D (ft-Lamberts)	B_V (ft-Lamberts)	Chart Location	Vertical Bar	Horizontal Bar	Average Resolution (Minutes of Arc)
1.	4%	12.3	0.7	D	3-5	3-5	1.38
				B	---	---	----
2.			2.4	D	3-6	3-6	1.24
				B	---	---	----
3.			6.4	D	4-1	4-1	1.10
				B	---	---	----
4.			27.5	D	3-6	3-6	1.24
				B	---	---	----
5.			88.0	D	3-6	3-6	1.24
				B	0-3	0-3	13.90
6.			310.0	D	3-6	3-6	1.24
				B	3-4	3-4	1.25
7.			975.0	D	3-3	3-3	1.74
				B	4-6	4-6	0.62
8.	4%	23.7	0.7	D	4-1	4-1	1.10
				B	---	---	----
9.			2.4	D	4-1	4-1	1.10
				B	---	---	----
10.			6.4	D	3-6	3-6	1.24
				B	---	---	----
11.			27.5	D	3-5	3-5	1.38
				B	---	---	----
12.			88.0	D	3-5	3-5	1.38
				B	---	---	----
13.			310.0	D	3-5	3-5	1.38
				B	2-2	2-2	3.93
14.			975.0	D	3-4	3-4	1.55
				B	4-6	4-6	0.62
15.	4%	50.5	0.7	D	4-1	4-1	1.10
				B	---	---	----
16.			2.4	D	4-1	4-1	1.10
				B	---	---	----

Table B-4.

Calibration of Resolution for the Right Field
Under All 175 Experimental Conditions (continued)

Condition	B_X	L_D (ft-Lamberts)	B_V (ft-Lamberts)	Chart Location	Vertical Bar	Horizontal Bar	Average Resolution (Minutes of Arc)
17.	4%	50.5	6.4	D	4-1	4-1	1.10
				B	---	---	----
18.			27.5	D	3-6	3-6	1.24
				B	---	---	----
19.			88.0	D	4-1	4-1	1.10
				B	---	---	----
20.			310.0	D	4-1	4-1	1.10
				B	1-5	1-5	5.53
21.			975.0	D	4-1	4-1	1.10
				B	4-3	4-3	0.87
22.	4%	105.0	0.7	D	4-2	4-2	0.98
				B	---	---	----
23.			2.4	D	4-2	4-2	0.98
				B	---	---	----
24.			6.4	D	4-1	4-1	1.10
				B	---	---	----
25.			27.5	D	4-1	4-1	1.10
				B	---	---	----
26.			88.0	D	4-1	4-1	1.10
				B	---	---	----
27.			310.0	D	4-1	4-1	1.10
				B	0-1	0-1	17.65
28.			975.0	D	3-6	3-6	1.24
				B	3-6	3-6	1.24
29.	4%	231.0	0.7	D	3-6	3-6	1.24
				B	---	---	----
30.			2.4	D	3-6	3-6	1.24
				B	---	---	----
31.			6.4	D	3-6	3-6	1.24
				B	---	---	----
32.			27.5	D	3-6	3-6	1.24
				B	---	---	----
33.			88.0	D	4-1	4-1	1.10
				B	---	---	----
34.			310.0	D	3-6	3-6	1.24
				B	---	---	----

Table B-4.

Calibration of Resolution for the Right Field
Under All 175 Experimental Conditions (continued)

Condition	B_X	L_D (ft-Lamberts)	B_V (ft-Lamberts)	Chart Location	Vertical Bar	Horizontal Bar	Average Resolution (Minutes of Arc)
35.	4%	231.0	975.0	D	3-6	3-6	1.24
				B	2-1	2-1	4.41
36.	10%	12.3	0.7	D	4-1	4-1	1.10
				B	---	---	----
37.			2.4	D	4-1	4-1	1.10
				B	---	---	----
38.			6.4	D	4-1	4-1	1.10
				B	---	---	----
39.			27.5	D	4-1	4-1	1.10
				B	0-4	0-4	12.39
40.			88.0	D	3-6	3-6	1.24
				B	1-3	1-3	6.95
41.			310.0	D	4-1	4-1	1.10
				B	4-1	4-1	1.10
42.			975.0	D	4-1	4-1	1.10
				B	4-6	4-6	0.62
43.	10%	23.7	0.7	D	4-1	4-1	1.10
				B	---	---	----
44.			2.4	D	4-1	4-1	1.10
				B	---	---	----
45.			6.4	D	4-1	4-1	1.10
				B	---	---	----
46.			27.5	D	4-1	4-1	1.10
				B	---	---	----
47.			88.0	D	3-6	3-6	1.24
				B	0-4	0-4	12.39
48.			310.0	D	4-1	4-1	1.10
				B	3-4	3-4	1.55
49.			975.0	D	4-1	4-1	1.10
				B	4-5	4-5	0.69
50.	10%	50.5	0.7	D	4-1	4-1	1.10
				B	---	---	----
51.			2.4	D	4-1	4-1	1.10
				B	---	---	----
52.			6.4	D	4-1	4-1	1.10
				B	---	---	----

Table B-4.

Calibration of Resolution for the Right Field
Under All 175 Experimental Conditions (continued)

Condition	B_X	L_D (ft-Lamberts)	B_V (ft-Lamberts)	Chart Location	Vertical Bar	Horizontal Bar	Average Resolution (Minutes of Arc)
53.	10%	50.5	27.5	D	4-1	4-1	1.10
				B	---	---	----
54.			88.0	D	4-1	4-1	1.10
				B	0-3	0-3	13.90
55.			310.0	D	4-1	4-1	1.10
				B	3-2	3-2	1.97
56.			975.0	D	4-1	4-1	1.10
				B	4-4	4-4	0.77
57.	10%	105.0	0.7	D	3-6	3-6	1.24
				B	---	---	----
58.			2.4	D	3-6	3-6	1.24
				B	---	---	----
59.			6.4	D	3-6	3-6	1.24
				B	---	---	----
60.			27.5	D	3-6	3-6	1.24
				B	---	---	----
61.			88.0	D	3-6	3-6	1.24
				B	0-1	0-1	17.65
62.			310.0	D	3-6	3-6	1.24
				B	3-2	3-2	1.97
63.			975.0	D	3-6	3-6	1.24
				B	4-2	4-2	0.98
64.	10%	231.0	0.7	D	3-6	3-6	1.24
				B	---	---	----
65.			2.4	D	3-6	3-6	1.24
				B	---	---	----
66.			6.4	D	3-6	3-6	1.24
				B	---	---	----
67.			27.5	D	3-6	3-6	1.24
				B	---	---	----
68.			88.0	D	3-6	3-6	1.24
				B	---	---	----
69.			310.0	D	3-6	3-6	1.24
				B	1-1	1-1	8.83
70.			975.0	D	3-6	3-6	1.24
				B	3-5	3-5	1.38

Table B-4.

Calibration of Resolution for the Right Field
Under All 175 Experimental Conditions (continued)

Condition	B_X	L_D (ft-Lamberts)	B_V (ft-Lamberts)	Chart Location	Vertical Bar	Horizontal Bar	Average Resolution (Minutes of Arc)
71.	25%	12.3	0.7	D	4-1	4-1	1.10
				B	---	---	----
72.			2.4	D	4-1	4-1	1.10
				B	---	---	----
73.			6.4	D	4-1	4-1	1.10
				B	---	---	----
74.			27.5	D	3-6	3-6	1.24
				B	1-4	1-4	6.20
75.			88.0	D	3-6	3-6	1.24
				B	1-6	1-6	4.95
76.			310.0	D	3-3	3-3	1.74
				B	4-3	4-3	0.87
77.			975.0	D	1-3	1-3	6.95
				B	5-1	5-1	0.55
78.	25%	23.7	0.7	D	4-1	4-1	1.10
				B	---	---	----
79.			2.4	D	4-1	4-1	1.10
				B	---	---	----
80.			6.4	D	4-1	4-1	1.10
				B	---	---	----
81.			27.5	D	4-1	4-1	1.10
				B	0-3	0-3	13.90
82.			88.0	D	4-1	4-1	1.10
				B	1-3	1-3	6.95
83.			310.0	D	3-4	3-4	1.55
				B	4-2	4-2	0.98
84.			975.0	D	2-6	2-6	2.48
				B	4-6	4-6	0.62
85.	25%	50.5	0.7	D	4-1	4-1	1.10
				B	---	---	----
86.			2.4	D	4-1	4-1	1.10
				B	---	---	----
87.			6.4	D	4-1	4-1	1.10
				B	---	---	----
88.			27.5	D	4-1	4-1	1.10
				B	---	---	----

Table B-4.

Calibration of Resolution for the Right Field Under All 175 Experimental Conditions (continued)

Condition	B_X	L_D (ft-Lamberts)	B_V (ft-Lamberts)	Chart Location	Vertical Bar	Horizontal Bar	Average Resolution (Minutes of Arc)
89.	25%	50.5	88.0	D	4-1	4-1	1.10
				B	1-2	1-2	7.86
90.			310.0	D	4-1	4-1	1.10
				B	3-4	3-4	1.55
91.			975.0	D	3-3	3-3	1.74
				B	4-4	4-4	0.77
92.	25%	105.0	0.7	D	3-6	3-6	1.24
				B	---	---	----
93.			2.4	D	3-6	3-6	1.24
				B	---	---	----
94.			6.4	D	3-6	3-6	1.24
				B	---	---	----
95.			27.5	D	3-6	3-6	1.24
				B	---	---	----
96.			88.0	D	3-6	3-6	1.24
				B	0-2	0-2	15.73
97.			310.0	D	3-6	3-6	1.24
				B	3-3	3-3	1.74
98.			975.0	D	3-5	3-5	1.38
				B	4-3	4-3	0.87
99.	25%	231.0	0.7	D	4-1	4-1	1.10
				B	---	---	----
100.			2.4	D	4-1	4-1	1.10
				B	---	---	----
101.			6.4	D	4-1	4-1	1.10
				B	---	---	----
102.			27.5	D	4-1	4-1	1.10
				B	---	---	----
103.			88.0	D	4-1	4-1	1.10
				B	---	---	----
104.			310.0	D	4-1	4-1	1.10
				B	2-5	2-5	2.76
105.			975.0	D	4-1	4-1	1.10
				B	4-3	4-3	0.87

Table B-4.

Calibration of Resolution for the Right Field
Under All 175 Experimental Conditions (continued)

Condition	B_X	L_D (ft-Lamberts)	B_V (ft-Lamberts)	Chart Location	Vertical Bar	Horizontal Bar	Average Resolution (Minutes of Arc)
106.	Trichroic	12.3	0.7	D	4-1	4-1	1.10
				B	---	---	----
107.			2.4	D	4-1	4-1	1.10
				B	---	---	----
108.			6.4	D	4-1	4-1	1.10
				B	---	---	----
109.			27.5	D	4-1	4-1	1.10
				B	0-4	0-4	12.39
110.			88.0	D	4-1	4-1	1.10
				B	1-4	1-4	6.20
111.			310.0	D	3-6	3-6	1.24
				B	4-3	4-3	0.87
112.			975.0	D	3-3	3-3	1.74
				B	5-1	5-1	0.55
113.	Trichroic	23.7	0.7	D	4-1	4-1	1.10
				B	---	---	----
114.			2.4	D	4-1	4-1	1.10
				B	---	---	----
115.			6.4	D	4-1	4-1	1.10
				B	---	---	----
116.			27.5	D	4-1	4-1	1.10
				B	0-3	0-3	13.90
117.			88.0	D	4-1	4-1	1.10
				B	0-6	0-6	9.91
118.			310.0	D	3-6	3-6	1.24
				B	4-1	4-1	1.10
119.			975.0	D	3-3	3-3	1.74
				B	4-6	4-6	0.62
120.	Trichroic	50.5	0.7	D	4-1	4-1	1.10
				B	---	---	----
121.			2.4	D	4-1	4-1	1.10
				B	---	---	----
122.			6.4	D	4-1	4-1	1.10
				B	---	---	----

Table B-4.

Calibration of Resolution for the Right Field
Under All 175 Experimental Conditions (continued)

Condition	B_X	L_D (ft-Lamberts)	B_V (ft-Lamberts)	Chart Location	Vertical Bar	Horizontal Bar	Average Resolution (Minutes of Arc)
123.	Trichroic	50.5	27.5	D	4-1	4-1	1.10
				B	---	---	----
124.			88.0	D	4-1	4-1	1.10
				B	0-4	0-4	12.39
125.			310.0	D	4-1	4-1	1.10
				B	3-5	3-5	1.38
126.			975.0	D	3-6	3-6	1.24
				B	4-3	4-3	0.87
127.	Trichroic	105.0	0.7	D	4-1	4-1	1.10
				B	---	---	----
128.			2.4	D	4-1	4-1	1.10
				B	---	---	----
129.			6.4	D	4-1	4-1	1.10
				B	---	---	----
130.			27.5	D	4-1	4-1	1.10
				B	---	---	----
131.			88.0	D	4-1	4-1	1.10
				B	0-1	0-1	17.65
132.			310.0	D	3-6	3-6	1.10
				B	2-4	2-4	3.10
133.			975.0	D	3-6	3-6	1.74
				B	4-2	4-2	0.98
134.	Trichroic	231.0	0.7	D	4-1	4-1	1.10
				B	---	---	----
135.			2.4	D	4-1	4-1	1.10
				B	---	---	----
136.			6.4	D	4-1	4-1	1.10
				B	---	---	----
137.			27.5	D	4-1	4-1	1.10
				B	---	---	----
138.			88.0	D	4-1	4-1	1.10
				B	---	---	----
139.			310.0	D	4-1	4-1	1.10
				B	1-3	1-3	6.95
140.			975.0	D	4-1	4-1	1.10
				B	4-2	4-2	0.98

Table B-4.

Calibration of Resolution for the Right Field
Under All 175 Experimental Conditions (continued)

Condition	B_X	L_D (ft-Lamberts)	B_V (ft-Lamberts)	Chart Location	Vertical Bar	Horizontal Bar	Average Resolution (Minutes of Arc)
141.	0%	12.3	0.7	D	4-1	4-1	1.10
				B	---	---	----
142.			2.4	D	4-1	4-1	1.10
				B	---	---	----
143.			6.4	D	4-1	4-1	1.10
				B	---	---	----
144.			27.5	D	4-1	4-1	1.10
				B	---	---	----
145.			88.0	D	4-1	4-1	1.10
				B	---	---	----
146.			310.0	D	4-1	4-1	1.10
				B	---	---	----
147.			975.0	D	4-1	4-1	1.10
				B	---	---	----
148.	0%	23.7	0.7	D	4-1	4-1	1.10
				B	---	---	----
149.			2.4	D	4-1	4-1	1.10
				B	---	---	----
150.			6.4	D	4-1	4-1	1.10
				B	---	---	----
151.			27.5	D	4-1	4-1	1.10
				B	---	---	----
152.			88.0	D	4-1	4-1	1.10
				B	---	---	----
153.			310.0	D	4-1	4-1	1.10
				B	---	---	----
154.			975.0	D	4-1	4-1	1.10
				B	---	---	----
155.	0%	50.5	0.7	D	4-1	4-1	1.10
				B	---	---	----
156.			2.4	D	4-1	4-1	1.10
				B	---	---	----
157.			6.4	D	4-1	4-1	1.10
				B	---	---	----

Table B-4.

Calibration of Resolution for the Right Field
Under All 175 Experimental Conditions (concluded)

Condition	B_X	L_D (ft-Lamberts)	B_V (ft-Lamberts)	Chart Location	Vertical Bar	Horizontal Bar	Average Resolution (Minutes of Arc)
158.	0%	50.5	27.5	D	4-1	4-1	1.10
				B	---	---	----
159.			88.0	D	4-1	4-1	1.10
				B	---	---	----
160.			310.0	D	4-1	4-1	1.10
				B	---	---	----
161.			975.0	D	4-1	4-1	1.10
				B	---	---	----
162.	0%	105.0	0.7	D	4-1	4-1	1.10
				B	---	---	----
163.			2.4	D	4-1	4-1	1.10
				B	---	---	----
164.			6.4	D	4-1	4-1	1.10
				B	---	---	----
165.			27.5	D	4-1	4-1	1.10
				B	---	---	----
166.			88.0	D	4-1	4-1	1.10
				B	---	---	----
167.			310.0	D	4-1	4-1	1.10
				B	---	---	----
168.			975.0	D	4-1	4-1	1.10
				B	---	---	----
169.	0%	231.0	0.7	D	4-1	4-1	1.10
				B	---	---	----
170.			2.4	D	4-1	4-1	1.10
				B	---	---	----
171.			6.4	D	4-1	4-1	1.10
				B	---	---	----
172.			27.5	D	4-1	4-1	1.10
				B	---	---	----
173.			88.0	D	4-1	4-1	1.10
				B	---	---	----
174.			310.0	D	4-1	4-1	1.10
				B	---	---	----
175.			975.0	D	4-1	4-1	1.10
				B	---	---	----

Table B-5.

Calibration of Luminance for Right Field with Background Projector Only

B_V (ft-Lamberts)	Projected Image	Luminance Range (ft-Lamberts)		Average Luminance (ft-Lamberts)
		High	Low	
0.7	C	0.7	0.5	0.6
	P	0.5	0.4	0.5
2.4	C	2.4	0.7	1.8
	P	1.1	0.9	1.0
6.4	C	6.4	1.4	4.8
	P	2.8	1.9	2.4
27.5	C	27.5	2.2	19.7
	P	13.0	6.7	10.4
88.0	C	88.0	4.7	61.5
	P	38.5	19.3	31.7
310.0	C	310.0	15.3	216.8
	P	163.0	43.5	118.1
975.0	C	975.0	41.0	687.7
	P	475.0	127.0	305.5

Table B-6.

Calibration of Luminance for Left Field with Background Projector Only

B_V (ft-Lamberts)	Projected Image	Luminance Range (ft-Lamberts)		Average Luminance (ft-Lamberts)
		High	Low	
0.7	C	1.4	0.7	1.1
	P	1.2	0.8	1.0
2.4	C	2.3	0.7	2.1
	P	1.9	1.3	1.6
6.4	C	7.0	0.9	5.2
	P	3.8	2.2	3.0
27.5	C	26.9	3.2	19.4
	P	11.5	6.3	10.1
88.0	C	94.5	10.1	67.6
	P	40.1	18.3	32.7
310.0	C	287.0	37.0	207.2
	P	135.0	50.0	104.0
975.0	C	990.0	50.5	690.1
	P	410.0	195.0	311.2

C = USAF Tri-bar Chart
P = Randomly generated reticulated pattern

Table B-7.

Calibration of Luminance for Displayed Image with Image Projector Only

L_D (ft-Lamberts)	Projected Image	Luminance Range (ft-Lamberts) High	Luminance Range (ft-Lamberts) Low	Average Luminance (ft-Lamberts)
12.3	C	12.3	0.7	8.2
	P	7.7	1.3	4.6
23.7	C	23.7	1.1	15.5
	P	15.7	4.3	11.3
50.5	C	50.5	1.8	34.2
	P	33.5	5.9	21.7
105.0	C	105.0	3.4	67.8
	P	72.5	29.6	51.5
231.0	C	231.0	11.3	162.6
	P	187.0	33.0	151.5

C = USAF Tri-bar Chart
P = Randomly Generated Reticulated Pattern

Table B-8.

Calibration of Luminance for Right Field
Under All 175 Experimental Conditions

Condition	Chart Position	Luminance Range (ft-Lamberts)		Average Luminance (ft-Lamberts)
		High	Low	
1.	D	10.5	0.6	5.6
	B	5.6	3.3	4.3
2.	D	10.8	0.8	7.2
	B	6.1	3.3	4.6
3.	D	11.0	0.9	7.3
	B	6.1	3.2	4.7
4.	D	11.3	1.2	7.6
	B	6.4	3.7	5.3
5.	D	11.9	2.2	8.3
	B	8.6	4.5	7.1
6.	D	15.3	4.5	11.2
	B	18.0	7.4	14.0
7.	D	23.5	10.5	16.8
	B	47.5	13.6	36.1
8.	D	21.1	1.1	12.4
	B	12.5	4.6	10.3
9.	D	21.0	1.4	13.2
	B	12.7	4.7	10.4
10.	D	21.3	1.5	13.6
	B	12.7	4.9	10.4
11.	D	22.0	1.6	14.2
	B	13.3	5.9	10.9
12.	D	22.7	2.4	15.2
	B	14.7	7.9	12.1
13.	D	25.6	5.5	18.5
	B	23.3	10.3	19.2
14.	D	34.5	13.3	27.3
	B	50.0	17.6	39.9
15.	D	45.0	1.7	27.1
	B	21.7	9.6	14.2

Table B-8.

Calibration of Luminance for Right Field
Under All 175 Experimental Conditions (continued)

Condition	Chart Position	Luminance Range (ft-Lamberts)		Average Luminance (ft-Lamberts)
		High	Low	
16.	D	34.5	1.8	27.3
	B	21.7	11.9	15.9
17.	D	45.0	2.1	29.6
	B	25.0	11.9	17.0
18.	D	45.5	2.6	30.1
	B	24.7	14.0	18.8
19.	D	47.0	3.2	30.6
	B	28.0	14.3	20.4
20.	D	49.5	6.0	33.4
	B	38.0	16.9	27.7
21.	D	61.5	14.3	41.9
	B	58.5	23.8	47.3
22.	D	93.0	2.9	55.5
	B	39.0	20.0	28.6
23.	D	94.0	3.6	59.1
	B	42.5	20.7	29.8
24.	D	94.5	3.8	60.4
	B	44.0	21.2	30.5
25.	D	94.5	4.3	61.2
	B	46.5	21.5	32.0
26.	D	96.5	5.7	62.5
	B	62.0	21.0	40.7
27.	D	100.2	7.7	65.1
	B	71.5	31.0	49.2
28.	D	107.0	15.3	72.8
	B	91.0	43.0	70.5
29.	D	186.0	7.1	119.3
	B	87.5	48.0	65.5
30.	D	187.0	7.1	119.5
	B	101.0	48.5	69.4

Table B-8.

Calibration of Luminance for Right Field
Under All 175 Experimental Conditions (continued)

Condition	Chart Position	Luminance Range (ft-Lamberts)		Average Luminance (ft-Lamberts)
		High	Low	
31.	D	187.0	7.2	119.3
	B	103.0	52.0	73.5
32.	D	187.0	7.5	120.5
	B	103.0	52.0	74.0
33.	D	187.0	8.4	121.1
	B	107.0	56.5	80.1
34.	D	187.0	10.9	121.2
	B	110.0	59.0	84.1
35.	D	200.0	17.3	131.1
	B	123.0	65.5	95.2
36.	D	10.5	0.8	7.0
	B	3.5	1.8	2.9
37.	D	10.7	0.9	7.2
	B	5.5	1.9	3.6
38.	D	11.0	1.9	7.4
	B	5.9	2.6	4.2
39.	D	12.0	1.6	8.1
	B	7.5	4.1	6.0
40.	D	13.7	3.3	9.6
	B	12.7	7.7	11.0
41.	D	21.7	11.3	17.6
	B	36.5	20.7	27.2
42.	D	49.5	32.5	42.0
	B	97.0	15.1	73.8
43.	D	20.3	1.1	11.9
	B	16.0	7.4	12.1
44.	D	20.3	1.2	13.1
	B	17.5	7.7	13.0
45.	D	22.0	1.4	14.0
	B	18.6	8.3	13.6

Table B-8.

Calibration of Luminance for Right Field
Under All 175 Experimental Conditions (continued)

Condition	Chart Position	Luminance Range (ft-Lamberts)		Average Luminance (ft-Lamberts)
		High	Low	
46.	D	22.0	2.2	14.7
	B	18.6	9.5	14.2
47.	D	24.9	4.0	19.1
	B	21.6	13.3	19.1
48.	D	32.0	10.9	24.6
	B	44.0	17.6	37.0
49.	D	54.5	35.0	48.7
	B	109.0	23.5	83.2
50.	D	43.5	1.9	28.1
	B	26.9	15.4	21.3
51.	D	44.0	2.0	28.3
	B	27.0	16.2	21.6
52.	D	44.5	2.2	28.4
	B	33.0	18.3	23.9
53.	D	45.5	2.6	29.2
	B	34.0	17.5	24.8
54.	D	48.5	5.6	31.6
	B	43.0	19.7	29.8
55.	D	56.5	14.1	39.3
	B	61.5	22.5	45.9
56.	D	86.5	40.5	63.9
	B	123.0	34.0	91.0
57.	D	89.0	3.5	57.0
	B	67.5	28.0	47.2
58.	D	89.5	3.7	58.4
	B	72.5	28.0	48.6
59.	D	90.5	3.8	59.2
	B	74.5	28.5	53.7
60.	D	93.5	4.4	59.6
	B	74.5	36.5	58.1

Table B-8.

Calibration of Luminance for Right Field
Under All 175 Experimental Conditions (continued)

Condition	Chart Position	Luminance Range (ft-Lamberts)		Average Luminance (ft-Lamberts)
		High	Low	
61.	D	97.0	7.6	62.1
	B	81.5	39.0	61.4
62.	D	100.0	16.0	69.2
	B	94.0	42.5	74.2
63.	D	120.0	39.0	92.1
	B	140.0	57.0	114.7
64.	D	177.0	6.8	114.7
	B	177.0	41.0	76.6
65.	D	177.0	7.1	114.8
	B	134.0	53.0	87.4
66.	D	177.0	7.2	115.3
	B	134.0	55.5	88.1
67.	D	182.0	7.9	116.7
	B	137.0	57.0	91.1
68.	D	183.0	9.6	118.4
	B	147.0	63.5	99.4
69.	D	183.0	14.9	119.2
	B	155.0	68.5	113.4
70.	D	205.0	30.3	140.1
	B	200.0	76.5	147.9
71.	D	10.2	0.8	6.8
	B	5.1	2.9	4.0
72.	D	10.3	1.0	6.9
	B	5.3	3.3	4.3
73.	D	10.7	1.4	7.3
	B	6.6	4.2	5.3
74.	D	12.6	3.1	9.3
	B	11.7	4.7	9.5
75.	D	17.5	7.8	14.1
	B	27.9	5.8	21.3

Table B-8.

Calibration of Luminance for Right Field
Under All 175 Experimental Conditions (continued)

Condition	Chart Position	Luminance Range (ft-Lamberts)		Average Luminance (ft·Lamberts)
		High	Low	
76.	D	37.0	24.4	33.2
	B	93.5	9.8	68.8
77.	D	97.0	74.0	89.5
	B	279.0	20.0	200.7
78.	D	20.1	1.2	12.6
	B	12.3	7.5	10.2
79.	D	20.5	1.3	12.8
	B	12.7	7.9	10.6
80.	D	21.1	1.7	13.4
	B	14.0	9.4	11.5
81.	D	21.0	3.3	15.4
	B	20.0	10.7	15.9
82.	D	28.7	7.7	20.6
	B	37.5	11.9	28.4
83.	D	50.2	23.6	40.8
	B	103.5	16.5	76.6
84.	D	116.0	71.9	98.2
	B	294.0	71.9	210.9
85.	D	42.0	1.8	26.9
	B	23.6	11.9	16.1
86.	D	43.2	2.1	27.3
	B	26.0	14.0	17.8
87.	D	43.5	2.5	27.7
	B	49.5	12.6	25.6
88.	D	45.2	4.5	30.0
	B	34.2	15.2	20.7
89.	D	52.9	10.0	35.6
	B	48.5	16.5	33.2
90.	D	79.9	30.1	56.8
	B	110.0	20.6	79.3

Table B-8.

Calibration of Luminance for Right Field
Under All 175 Experimental Conditions (continued)

Condition	Chart Position	Luminance Range (ft-Lamberts)		Average Luminance (ft-Lamberts)
		High	Low	
91.	D	156.0	88.8	115.7
	B	297.0	31.0	209.7
92.	D	84.0	3.4	54.5
	B	43.3	17.2	34.4
93.	D	84.5	3.8	54.9
	B	45.2	18.0	35.7
94.	D	85.5	4.2	55.9
	B	50.5	28.9	40.2
95.	D	91.0	6.6	58.2
	B	58.0	29.6	45.0
96.	D	97.5	11.9	65.1
	B	73.5	35.2	54.3
97.	D	123.0	32.2	83.4
	B	137.0	37.5	97.6
98.	D	211.0	95.2	149.3
	B	309.0	42.0	224.0
99.	D	176.0	6.8	114.1
	B	84.5	51.5	66.4
100.	D	175.0	7.1	113.8
	B	92.3	60.0	75.4
101.	D	178.0	7.4	114.5
	B	91.5	62.0	76.1
102.	D	175.0	8.6	114.6
	B	104.0	62.2	80.0
103.	D	186.0	13.5	121.1
	B	105.3	64.0	87.1
104.	D	211.0	31.0	139.5
	B	168.0	68.5	128.6
105.	D	297.0	89.5	202.1
	B	312.0	78.5	237.4

Table B-8.

Calibration of Luminance for Right Field
Under All 175 Experimental Conditions (continued)

Condition	Chart Position	Luminance Range (ft-Lamberts)		Average Luminance (ft-Lamberts)
		High	Low	
106.	D	10.2	0.9	6.8
	B	5.7	3.1	4.3
107.	D	10.2	0.9	6.9
	B	6.1	3.2	4.9
108.	D	10.7	1.1	6.9
	B	5.7	3.2	4.6
109.	D	11.5	1.9	7.9
	B	9.4	3.6	7.3
110.	D	14.7	4.0	10.2
	B	16.5	4.7	12.5
111.	D	27.5	12.6	21.0
	B	49.0	9.4	35.5
112.	D	57.5	32.7	46.9
	B	143.0	17.3	95.9
113.	D	19.9	1.2	13.1
	B	11.4	7.0	9.9
114.	D	20.3	1.3	13.2
	B	13.6	7.2	10.7
115.	D	20.8	1.5	13.2
	B	13.8	7.9	10.8
116.	D	21.2	2.3	13.8
	B	16.5	10.3	12.8
117.	D	23.0	4.0	15.8
	B	23.9	11.8	18.1
118.	D	33.2	11.0	34.9
	B	53.5	15.3	40.1
119.	D	68.5	30.5	52.1
	B	145.0	24.5	99.4
120.	D	43.9	1.9	27.8
	B	22.7	11.6	17.1

Table B-8.

Calibration of Luminance for Right Field
Under All 175 Experimental Conditions (continued)

Condition	Chart Position	Luminance Range (ft-Lamberts)		Average Luminance (ft-Lamberts)
		High	Low	
121.	D	43.9	2.2	27.8
	B	27.1	13.7	20.7
122.	D	44.5	2.3	28.2
	B	29.0	13.9	21.6
123.	D	45.0	3.2	26.8
	B	32.3	16.8	23.8
124.	D	47.5	5.2	31.3
	B	39.5	17.4	29.3
125.	D	53.0	13.3	37.6
	B	70.5	22.7	51.9
126.	D	82.5	36.5	62.6
	B	160.0	31.3	112.8
127.	D	90.5	3.5	56.9
	B	58.3	17.7	40.1
128.	D	91.5	3.6	58.3
	B	58.5	18.0	40.1
129.	D	92.5	3.9	59.3
	B	62.0	32.5	46.5
130.	D	94.5	4.7	60.5
	B	63.0	36.0	48.0
131.	D	97.0	6.5	62.0
	B	65.0	36.5	50.7
132.	D	104.0	14.6	70.8
	B	97.0	41.0	74.7
133.	D	122.0	32.5	92.4
	B	167.0	48.5	125.6
134.	D	176.0	6.7	111.0
	B	84.5	48.5	64.6
135.	D	177.0	6.7	114.4
	B	85.0	48.5	65.4

Table B-8.

Calibration of Luminance for Right Field
Under All 175 Experimental Conditions (continued)

Condition	Chart Position	Luminance Range (ft-Lamberts) High	Luminance Range (ft-Lamberts) Low	Average Luminance (ft-Lamberts)
136.	D	177.0	6.9	114.7
	B	99.0	52.5	70.0
137.	D	177.0	7.8	115.2
	B	95.6	55.5	70.3
138.	D	176.0	10.0	115.7
	B	107.0	61.5	77.1
139.	D	187.0	19.0	123.5
	B	122.0	75.5	96.7
140.	D	215.0	45.5	146.1
	B	199.0	84.5	148.4
141.	D	10.5	0.8	6.4
	B	6.7	1.5	4.1
142.	D	10.5	0.8	6.9
	B	6.6	2.2	4.3
143.	D	10.7	0.9	7.1
	B	6.8	2.8	4.6
144.	D	10.9	1.0	7.3
	B	6.8	2.3	4.5
145.	D	11.1	1.2	7.5
	B	6.6	3.0	5.2
146.	D	11.7	1.9	8.3
	B	9.5	4.3	7.7
147.	D	13.7	3.8	10.4
	B	16.3	7.6	12.9
148.	D	19.7	1.1	12.7
	B	9.7	3.6	7.4
149.	D	20.5	1.2	13.0
	B	14.3	6.1	9.9
150.	D	20.1	1.2	13.1
	B	14.0	4.8	8.9

Table B-8.

Calibration of Luminance for Right Field
Under All 175 Experimental Conditions (continued)

Condition	Chart Position	Luminance Range (ft-Lamberts) High	Luminance Range (ft-Lamberts) Low	Average Luminance (ft-Lamberts)
151.	D	20.1	1.3	13.2
	B	12.5	6.7	9.5
152.	D	20.3	1.5	13.3
	B	13.3	8.4	10.2
153.	D	21.0	2.2	14.0
	B	13.0	10.1	11.8
154.	D	22.8	4.1	16.4
	B	22.0	12.3	18.5
155.	D	41.0	1.6	25.5
	B	20.8	8.0	15.7
156.	D	41.5	1.9	26.8
	B	24.8	7.8	16.9
157.	D	42.5	2.0	27.2
	B	22.2	6.8	15.4
158.	D	43.0	2.0	27.4
	B	26.3	7.5	17.2
159.	D	43.0	2.3	27.6
	B	24.8	7.5	16.7
160.	D	43.5	3.0	28.7
	B	28.0	13.0	20.0
161.	D	46.5	4.8	31.1
	B	38.2	15.5	29.0
162.	D	89.9	3.7	56.3
	B	48.5	18.3	33.8
163.	D	89.9	3.5	57.6
	B	53.0	18.5	36.5
164.	D	89.5	3.6	57.9
	B	58.0	16.5	39.9
165.	D	89.5	3.7	56.9
	B	55.0	21.3	40.2

Table B-8.

Calibration of Luminance for Right Field
Under All 175 Experimental Conditions (concluded)

Condition	Chart Position	Luminance Range (ft-Lamberts)		Average Luminance (ft-Lamberts)
		High	Low	
166.	D	90.5	3.9	57.3
	B	55.5	22.5	39.4
167.	D	91.0	4.6	58.4
	B	56.5	17.3	39.6
168.	D	92.5	6.7	60.8
	B	54.5	26.0	45.3
169.	D	174.0	6.3	108.6
	B	99.5	33.0	70.6
170.	D	174.0	6.4	110.7
	B	100.0	33.5	70.7
171.	D	174.0	6.5	111.2
	B	100.0	33.5	71.0
172.	D	170.0	6.6	111.0
	B	101.0	34.5	71.5
173.	D	176.0	6.8	113.8
	B	102.5	35.0	72.5
174.	D	176.0	7.8	114.4
	B	103.0	37.5	74.9
175.	D	179.0	9.6	116.6
	B	107.0	42.5	80.6

APPENDIX C

EXPERIMENTAL DATA

Table C-1 presents the experimental data averaged across the four subjects for all 175 conditions.

In Tables C-2 and C-3 this data is averaged across subjects and display luminance, L_D, for both the display and background projected charts respectively.

In Tables C-4 and C-5 it is averaged across subjects and beamsplitter transmittance, B_X, for the display and background charts respectively.

Table C-1.

Experimental Data Averaged Across the Four Observers for All 175 Conditions

Condition	Average Resolution (Minutes of Arc)	S.D.	Average Time (Seconds)	S.D.	C_{max} (%)	B_{Δ}
1.	1.75	0.28	7.93	6.29	99.49	16.91
2.	1.79	0.34	7.47	6.36	99.08	4.96
3.	1.82	0.39	6.71	4.90	95.78	1.89
4.	1.76	0.25	7.54	5.72	84.30	0.47
5.	1.78	0.27	7.47	7.01	62.79	0.17
6.	2.26	0.97	9.25	8.22	32.25	0.08
7.	6.25	5.06	12.21	10.88	13.15	0.05
8.	1.69	0.26	6.66	6.41	99.75	32.54
9.	1.73	0.26	5.83	4.57	99.16	9.52
10.	1.66	0.27	5.35	3.38	97.80	3.59
11.	1.68	0.30	5.91	4.03	91.18	0.87
12.	1.61	0.27	6.01	3.24	76.37	0.30
13.	1.75	0.39	5.54	3.37	47.85	0.11
14.	2.56	1.22	6.57	5.24	22.58	0.06
15.	1.64	0.20	5.03	3.20	99.88	69.30
16.	1.60	0.17	4.32	2.43	99.61	20.24
17.	1.63	0.23	4.91	3.16	99.47	7.61
18.	1.66	0.34	4.63	2.92	95.66	1.80
19.	1.57	0.23	5.00	3.23	87.32	0.59
20.	1.58	0.23	4.54	2.48	66.17	0.20
21.	1.71	0.19	4.61	2.46	38.33	0.09
22.	1.63	0.21	4.89	2.87	99.94	144.04
23.	1.59	0.16	7.47	1.40	99.81	42.04
24.	1.59	0.19	4.41	2.17	99.49	15.79
25.	1.60	0.16	3.90	1.74	97.86	3.70

Table C-1.

Experimental Data Averaged Across the Four Observers for All 175 Conditions (continued)

Condition	Average Resolution (Minutes of Arc)	S.D.	Average Time (Seconds)	S.D.	C_{max} (%)	B_{Δ}
26.	1.63	0.19	3.83	1.79	93.47	1.18
27.	1.61	0.13	4.08	1.97	80.25	0.36
28.	1.70	0.15	4.08	2.14	56.38	0.14
29.	1.70	0.22	4.28	2.15	99.97	316.84
30.	1.65	0.17	4.46	2.60	99.91	92.44
31.	1.64	0.19	4.21	2.30	99.77	34.69
32.	1.66	0.23	4.88	4.46	99.02	8.10
33.	1.73	0.25	4.24	1.94	96.92	2.56
34.	1.36	0.21	3.97	2.12	89.94	0.75
35.	1.70	0.26	4.92	3.04	73.98	0.27
36.	1.77	0.15	4.61	2.31	98.75	15.91
37.	1.76	0.16	4.69	2.37	95.84	4.71
38.	1.77	0.17	4.24	1.99	89.63	1.83
39.	1.76	0.19	4.26	1.75	66.81	1.75
40	1.81	0.17	4.65	2.01	38.61	0.22
41.	3.64	2.09	5.57	2.45	15.15	0.14
42.	10.07	5.28	8.20	6.00	5.37	0.11
43.	1.73	0.21	4.53	2.26	99.35	30.57
44.	1.67	0.16	4.05	2.10	97.80	8.99
45.	1.68	0.17	4.18	1.63	94.34	3.43
46.	1.71	0.14	4.04	1.83	79.50	0.88
47.	1.66	0.09	4.07	1.84	54.79	0.34
48.	2.20	0.18	4.56	2.02	25.60	0.17
49.	6.84	2.99	5.91	2.92	9.80	0.12
50.	1.65	0.12	3.82	1.86	99.69	65.03

Table C-1.

Experimental Data Averaged Across the Four Observers for All 175 Conditions (continued)

Condition	Average Resolution (Minutes of Arc)	S.D.	Average Time (Seconds)	S.D.	C_{max} (%)	B_{Δ}
51.	1.61	0.13	4.45	1.28	99.00	19.94
52.	1.56	0.11	3.34	1.35	97.56	8.10
53.	1.57	0.09	3.68	2.13	89.22	1.75
54.	1.59	0.11	3.88	2.11	72.08	0.62
55.	1.78	0.13	4.22	1.89	42.30	0.25
56.	2.19	0.36	4.58	2.75	18.90	0.15
57.	1.57	0.13	3.83	1.86	99.85	135.10
58.	1.53	0.12	3.13	1.19	99.49	39.47
59.	1.52	0.12	3.16	1.17	99.66	14.87
60.	1.52	0.11	2.92	0.94	94.50	3.54
61.	1.53	0.12	3.74	1.50	84.30	1.17
62.	1.56	0.16	3.40	1.34	60.38	0.40
63.	1.71	0.12	3.46	1.49	32.64	0.20
64.	1.57	0.13	3.33	1.30	99.93	297.10
65.	1.55	0.13	3.68	1.90	99.77	86.72
66.	1.51	0.16	3.33	1.51	99.39	32.58
67.	1.52	0.18	3.16	1.43	97.42	7.66
68.	1.53	0.18	3.01	1.38	92.19	2.46
69.	1.56	0.20	3.38	1.17	77.02	0.77
70.	1.63	0.18	3.67	1.53	51.60	0.31
71.	1.69	0.11	3.92	1.77	96.34	13.43
72.	1.70	0.13	3.13	1.45	88.49	4.09
73.	1.70	0.17	3.14	1.46	74.24	1.69
74.	1.71	0.17	5.36	1.75	35.25	0.70
75.	1.81	0.23	3.05	1.07	17.33	0.35

Table C-1.

Experimental Data Averaged Across the Four Observers for All 175 Conditions (continued)

Condition	Average Resolution (Minutes of Arc)	S.D.	Average Time (Seconds)	S.D.	C_{max} (%)	B_{Δ}
76.	7.18	5.45	4.44	2.49	5.62	0.28
77.	12.90	5.65	4.49	3.41	1.86	0.26
78.	1.63	0.09	3.42	1.44	98.07	25.63
79.	1.66	0.15	3.25	1.67	93.67	7.65
80.	1.60	0.08	3.57	1.93	84.74	3.03
81.	1.59	0.07	3.42	1.51	56.38	0.90
82.	1.71	0.12	3.30	1.44	28.77	0.45
83.	3.39	1.32	5.26	3.05	10.28	0.31
84.	11.90	5.22	4.94	2.45	3.52	0.27
85.	1.62	0.10	3.73	1.77	99.08	54.34
86.	1.63	0.09	3.20	1.48	96.93	16.03
87.	1.58	0.06	3.08	1.17	92.21	6.17
88.	1.59	0.07	2.96	1.11	73.37	1.63
89.	1.62	0.10	3.19	1.20	46.27	0.68
90.	2.03	0.30	4.40	2.48	19.63	0.37
91.	6.65	2.92	5.63	3.23	7.21	0.29
92.	1.59	0.09	3.56	1.57	99.56	112.74
93.	1.61	0.08	3.54	1.47	98.50	33.06
94.	1.61	0.12	3.33	1.68	96.09	12.55
95.	1.59	0.11	3.30	1.72	85.14	3.11
96.	1.58	0.12	3.43	1.44	64.15	1.14
97.	1.80	0.16	4.23	1.93	33.69	0.50
98.	3.64	2.44	4.96	2.36	13.91	0.33
99.	1.76	0.45	3.45	1.75	99.80	247.74
100.	1.69	0.44	3.19	1.58	99.31	72.44

Table C-1.

Experimental Data Averaged Across the Four Observers for All 175 Conditions (continued)

Condition	Average Resolution (Minutes of Arc)	S. D.	Average Time (Seconds)	S. D.	C_{max} (%)	B_{Δ}
101.	1.65	0.24	3.42	2.09	98.19	27.32
102.	1.60	0.17	2.79	1.18	92.65	6.55
103.	1.59	0.18	2.88	1.14	79.75	2.22
104.	1.71	0.24	3.05	1.34	53.78	0.81
105.	2.02	0.43	4.50	2.64	26.22	0.43
106.	1.67	0.11	3.77	1.88		
107.	1.70	0.16	2.96	1.12		
108.	1.69	0.15	3.28	1.59		
109.	1.72	0.16	3.75	2.08		
110.	1.76	0.21	3.93	2.01		
111.	2.20	0.39	4.64	2.49		
112.	6.28	2.31	6.42	4.58		
113.	1.35	0.09	3.67	1.89		
114.	1.65	0.09	2.83	1.18		
115.	1.65	0.09	3.17	1.87		
116.	1.65	0.09	3.39	2.35		
117.	1.66	0.12	3.93	2.46		
118.	1.79	0.09	3.91	2.30		
119.	4.23	2.67	4.44	2.45		
120.	1.66	0.14	4.01	2.44		
121.	1.67	0.13	3.67	2.18		
122.	1.67	0.11	4.38	3.23		
123.	1.65	0.09	4.05	3.20		
124.	1.68	0.13	4.10	3.06		
125.	1.73	0.15	3.88	2.21		

Table C-1.

Experimental Data Averaged Across the Four Observers for All 175 Conditions (continued)

Condition	Average Resolution (Minutes of Arc)	S.D.	Average Time (Seconds)	S.D.	C_{max} (%)	B_{Δ}
126.	2.16	0.55	4.69	2.88		
127.	1.69	0.14	3.77	2.22		
128.	1.66	0.11	3.32	2.14		
129.	1.64	0.09	2.95	1.56		
130.	1.63	0.13	3.26	2.01		
131.	1.64	0.15	3.36	2.27		
132.	1.66	0.21	3.01	1.43		
133.	1.93	0.32	3.04	1.14		
134.	1.65	0.09	3.19	1.15		
135.	1.65	0.09	3.11	1.37		
136.	1.64	0.09	3.75	1.99		
137.	1.64	0.09	3.21	1.97		
138.	1.65	0.09	3.56	2.50		
139.	1.65	0.09	3.41	1.97		
140.	1.72	0.11	3.80	2.71		
141.	1.75	0.13	3.52	1.71	100.00	17.57
142.	1.85	0.49	3.00	1.47	100.00	5.12
143.	1.73	0.12	3.11	1.57	100.00	1.92
144.	1.70	0.10	2.91	1.01	100.00	0.45
145.	1.74	0.14	3.60	2.09	100.00	0.14
146.	1.75	0.15	3.18	1.43	100.00	0.04
147.	1.81	0.18	4.21	2.76	100.00	0.01
148.	1.76	0.10	3.68	1.80	100.00	33.86
149.	1.76	0.10	3.52	2.12	100.00	9.87
150.	1.76	0.10	3.66	2.54	100.00	3.70

Table C-1.

Experimental Data Averaged Across the Four Observers for all 175 Conditions (concluded)

Condition	Average Resolution (Minutes of Arc)	S.D.	Average Time (Seconds)	S.D.	C_{max} (%)	B_{Δ}
151.	1.76	0.08	2.90	1.23	100.00	0.86
152.	1.72	0.11	2.88	0.93	100.00	0.27
153.	1.72	0.09	3.28	1.85	100.00	0.08
154.	1.78	0.10	3.50	2.08	100.00	0.02
155.	1.68	0.11	3.44	1.93	100.00	72.14
156.	1.72	0.11	3.37	1.84	100.00	21.04
157.	1.75	0.13	3.52	2.21	100.00	7.89
158.	1.73	0.11	3.45	2.37	100.00	1.84
159.	1.72	0.11	3.48	1.97	100.00	0.57
160.	1.69	0.11	3.85	2.77	100.00	0.16
161.	1.72	0.11	3.97	3.40	100.00	0.05
162.	1.70	0.13	3.16	1.78	100.00	150.00
163.	1.70	0.10	2.97	1.35	100.00	43.75
164.	1.69	0.11	2.77	0.90	100.00	16.41
165.	1.70	0.12	2.76	1.67	100.00	3.82
166.	1.67	0.11	2.69	0.81	100.00	1.19
167.	1.67	0.11	3.74	2.94	100.00	0.34
168.	1.73	0.15	3.31	1.74	100.00	0.11
169.	1.69	0.09	3.24	2.00	100.00	330.00
170.	1.68	0.11	2.63	0.90	100.00	96.25
171.	1.69	0.13	2.63	1.76	100.00	36.09
172.	1.73	0.13	3.03	2.08	100.00	8.40
173.	1.72	0.11	2.92	1.27	100.00	2.62
174.	1.69	0.13	2.79	1.55	100.00	0.74
175.	1.69	0.09	2.95	1.90	100.00	0.24

Table C-2.

Horizontal Resolution and Time Collapsed Across L_D for the Display-Projected Chart

Dependent Variable: Resolution (Minutes of Arc)

		B_V (ft-Lamberts)							Average
		0.7	2.4	6.4	27.5	88.0	310.0	975.0	
B_X	4%	1.68	1.67	1.67	1.67	1.77	1.77	2.79	1.85
	10%	1.66	1.62	1.61	1.61	1.62	2.15	4.49	2.11
	25%	1.66	1.66	1.63	1.61	1.66	3.22	7.42	2.69
	Trichroic	1.66	1.67	1.66	1.65	1.68	1.81	3.26	1.91
	0%	1.72	1.75	1.73	1.73	1.71	1.71	1.75	1.73
	Average	1.68	1.67	1.66	1.66	1.67	2.13	3.94	

Dependent Variable: Time (Seconds)

		B_V (ft-Lamberts)							Average
		0.7	2.4	6.4	27.5	88.0	310.0	975.0	
B_X	4%	5.76	5.31	5.12	5.37	5.27	5.48	6.48	5.54
	10%	4.00	3.78	3.65	3.61	3.86	4.21	5.18	4.04
	25%	3.62	3.26	3.31	3.17	3.17	4.28	4.90	3.67
	Trichroic	3.68	3.18	3.51	3.53	3.78	3.77	4.48	3.70
	0%	3.41	3.10	3.19	3.11	3.11	3.37	3.59	3.27
	Average	4.09	3.72	3.75	3.76	3.84	4.22	4.93	

Table C-3.

Horizontal Resolution and Time Across L_D for the Background-Projected Chart

Dependent Variable: Resolution (Minutes of Arc)

		B_V (ft-Lamberts)							Average
		0.7	2.4	6.4	27.5	88.0	310.0	975.0	
B_X	4%	4.64	2.65	2.25	2.03	1.87	1.64	1.42	2.36
	10%	5.24	2.71	2.38	2.15	1.99	1.70	1.42	2.51
	25%	4.47	2.61	2.27	2.06	1.96	1.59	1.42	2.34
	Trichroic	4.51	2.59	2.29	2.16	1.98	1.67	1.38	2.37
	0%	4.60	2.89	2.26	2.18	2.04	1.78	1.52	2.47
	Average	4.69	2.69	2.29	2.12	1.97	1.68	1.43	

Dependent Variable: Time (Seconds)

		B_V (ft-Lamberts)							Average
		0.7	2.4	6.4	27.5	88.0	310.0	975.0	
B_X	4%	6.67	6.24	5.04	5.27	5.70	5.13	5.11	5.59
	10%	4.35	4.46	3.82	4.06	4.49	3.93	3.78	4.13
	25%	4.03	3.94	3.77	4.30	4.14	3.90	3.56	3.95
	Trichroic	3.71	4.16	3.86	4.30	4.24	3.87	4.03	4.02
	0%	3.63	3.95	3.38	3.82	3.46	3.67	3.77	3.67
	Average	4.48	4.55	3.97	4.35	4.40	4.10	4.05	

Table C-4.

Horizontal Resolution and Time Collapsed Across B_X for the Display-Projected Chart

Dependent Variable: Resolution (Minutes of Arc)

L_D (ft-Lamberts)	B_V (ft-Lamberts) 0.7	2.4	6.4	27.5	88.0	310.0	975.0	Average
12.3	1.73	1.76	1.74	1.73	1.78	3.40	7.46	2.80
23.7	1.69	1.69	1.67	1.68	1.67	2.17	5.46	2.29
50.5	1.65	1.65	1.64	1.64	1.63	1.76	2.89	1.84
105.0	1.63	1.62	1.61	1.61	1.61	1.66	2.14	1.70
231.0	1.68	1.65	1.63	1.63	1.64	1.65	1.75	1.66
Average	1.68	1.67	1.66	1.66	1.67	2.13	3.94	

Dependent Variable: Time (Seconds)

L_D (ft-Lamberts)	B_V (ft-Lamberts) 0.7	2.4	6.4	27.5	88.0	310.0	975.0	Average
12.3	4.75	4.25	4.10	4.37	4.54	5.41	7.11	4.93
23.7	4.39	3.90	3.99	3.93	3.99	4.51	5.07	4.25
50.5	4.01	3.58	3.84	3.76	3.93	4.18	4.72	4.00
105.0	3.82	3.49	3.32	3.33	3.41	3.69	3.77	3.55
231.0	3.50	3.41	3.52	3.41	3.32	3.30	3.97	3.49
Average	4.09	3.72	3.75	3.76	3.84	4.22	4.93	

Table C-5.

Horizontal Resolution and Time Collapsed Across B_X for the Background-Projected Chart

Dependent Variable: Resolution (Minutes of Arc)

L_D (ft-Lamberts)	B_V (ft-Lamberts) 0.7	2.4	6.4	27.5	88.0	310.0	975.0	Average
12.3	4.90	2.66	2.31	2.16	1.97	1.64	1.41	2.44
23.7	4.67	2.66	2.26	2.09	1.94	1.66	1.40	2.38
50.5	4.46	2.61	2.26	2.09	1.93	1.66	1.42	2.35
105.0	4.66	2.67	2.31	2.11	2.00	1.70	1.46	2.41
231.0	4.76	2.86	2.30	2.13	2.01	1.73	1.45	2.46
Average	4.69	2.69	2.29	2.12	1.97	1.68	1.43	

Dependent Variable: Time (Seconds)

L_D (ft-Lamberts)	B_V (ft-Lamberts) 0.7	2.4	6.4	27.5	88.0	310.0	975.0	Average
12.3	5.40	5.09	4.56	4.91	5.18	4.68	4.75	4.94
23.7	4.42	4.75	4.34	4.33	4.77	4.18	4.10	4.41
50.5	4.23	4.42	3.69	4.20	3.89	4.09	4.08	4.09
105.0	4.33	4.30	3.80	4.33	4.23	3.74	3.71	4.06
231.0	4.01	4.19	3.47	3.99	3.94	3.81	3.62	3.86
Average	4.47	4.54	3.97	4.35	4.40	4.10	4.05	